Rural Mechanisation

A Driver in Agricultural Change and Rural Development

Editors
M. A. Sattar Mandal
Stephen D. Biggs
Scott E. Justice

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First Published, 2017

Cover Design by Sk. Jabeer Al Sherazy

Price: BDT 1,000
US $ 25

ISBN 978 984 34 2253 8

Printed by Usha Art Press, 127/1, Lalbagh Road, Dhaka-1211, Bangladesh.

Dedicated

to

Numerous Rural Mechanics Who

Paved the Way for Rapid Rural Mechanisation in Bangladesh

Contents

List of Tables and Figures

Tables

Figures

Abbreviations and Acronyms

2WT	Two-wheel Tractor
4WT	Four- wheel Tractor
A/D/C	Agricultural Development Council
Acre	1 Hectare= 2.471 Acres
ADAB	Agricultural Development Agencies in Bangladesh
ADS	Agricultural Development Strategy
AED	Agricultural Engineering Division
AEPC	Alternative Energy Promotion Centre
AIRC	Agricultural Implement Research Centre
Aman rice	Summer Rice Grown during July/August-November/December
AMS	Agricultural Mechanisation Strategy
Aus rice	Summer Rice Grown during April/May-July-August
BADC	Bangladesh Agricultural Development Corporation
BAI	Bangladesh Agricultural Institute
BAMMA	Bangladesh Agriculture Machinery Manufacturers Association
BARC	Bangladesh Agricultural Research Council
BARD	Bangladesh Academy for Rural Development
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BDS	Business Development Service
BFRI	Bangladesh Fisheries Research Institute
BIDS	Bangladesh Institute of Development Studies
Bigha	1 *Bigha* = One Third of an Acre
BIHS	Bangladesh Integrated Household Survey
BITAC	Bangladesh Industrial and Technical Assistance Centre
BJMC	Bangladesh Jute Mills Corporation
BJRI	Bangladesh Jute Research Institute
BJSA	Bangladesh Jute Spinners association
BLRI	Bangladesh Livestock Research Institute
BMTF	Bangladesh Machine Tool Factory
Boro rice	Winter Rice Grown during December/January-April/May
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute

BSCIC	Bangladesh Small and Cottage Industries Corporation
BSERT	Bureau of Socioeconomic Research and Training
BSMS	Bangladesh *Shilpa Malik Samity*
BSRI	Bangladesh Sugarcane Research Institute
BTRI	Bangladesh Tea Research Institute
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
BWRC	Bangladesh Wheat Research Centre
CBO	Community Based Organisation
CBS	Central Bureau of Statistics
CGIAR	Consultative Group on International Agricultural Research
CGS	Competitive Grant System
Chatal	Rice Mills Attached Cemented Floor Used for Sun Drying of Parboiled Paddy
CNG	Compressed Natural Gas
CIAE	Central Institute of Agricultural Engineering
CIMMYT	International Centre for Maize and Wheat Research
CSISA	Cereal Systems Initiatives for South Asia
DAE	Department of Agricultural Extension
DATA	Data Analysis and Technical Assistance
DFID	Department for International Development
DFPM	Department of Farm Power and Machinery
Dheki	Foot Operated Long Thick Pole Fixed with Pestle for Dehusking Paddy
Doon	Conical Boat Like Structure Used for Lifting Irrigation Water from Canal
DSR	Directly Seeded Rice
DTW	Deep Tube Well
EPZ	Export Processing Zone
FAO	Food and Agriculture Organisation of the United Nations
FACASI	Farm Mechanisation and Conservation Agriculture for Sustainable Intensification
FICCI	Federation of Indian Chamber of Commerce and Industries
FOAB	Foundry Owners Association of Bangladesh
FTF	Feed the Future
GoB	Government of the People's Republic of Bangladesh
Ha	Hectare
HIES	Household Income and Expenditure Survey
HYV	High Yielding Variety

IDCOL	Infrastructure Development Company Limited
IDA	International Development Agency
IDE	International Development Enterprise
IFDC	International Fertiliser Development Corporation
IFPRI	International Food Policy Research Institute
IIMI	International Irrigation Management Institute (Renamed as IWMI)
IRRI	International Rice Research Institute
ITDG	Intermediate Technology Development Group
IWM	Irrigation and Water Management
KGF	Krishi Gobeshona Foundation (Agricultural Research Foundation)
Lakh	1 Lakh= One Hundred Thousand
LLP	Low Lift Pump
Maund	1 *Maund* = Approx. 40 kgs
MAWTS	Mirpur Agricultural Workshop and Training School
MFI	Micro Finance Institution
MNT	Medical Nutrient Therapeutic
MoAD	Ministry of Agricultural Development (Nepal)
MoF	Ministry of Finance, Nepal
MoFDM	Ministry of Food and Disaster Management
MOSTI	Manually Operated Shallow Tube well Irrigation
MPPT	Maximum Power Point Tracking
msl	Mean Sea Level
Mt	Metric Ton
NARS	National Agricultural Research System
NARS	Nepal Agricultural Research System
NGO	Non Government Organisation
NWRP	National Wheat Research Programme
PAC	Project Advisory Committee
PBKS	Palli Badhu Kalyan Samity
PFDS	Public Food Distribution System
PRSSP	Policy Research and Strategy Support Programme
PSU	Primary Sampling Unit
PT	Power Tiller
R&D	Research and Development
RCT	Resource Conservation Technologies
RD&E	Research Development and Extension
RDA	Rural Development Academy
RDRS	Rangpur Dinajpur Rural Service
REB	Rural Electrification Board

REFPI	Research and Extension in Farm Power Issues
RNF	Rural Non Farm
Rs.	Rupees (1 Indian Rupee= Approx. USD 0.015)
Rs.	Rupees (1 Nepalese Rupee= Approx. USD 0.0092)
SHG	Self Help Group
SIPS	Structural Insulated Panels
SIS	Solar Irrigation System
SLA	Sustainable Livelihoods Approach
SME	Small and Medium Enterprise
STW	Shallow Tube well
Taka/Tk./BDT	Bangladesh Currency (1 BDT/Taka/Tk.= Approx.USD 0.0125)
TCF	Trillion Cubic Feet
UNAPCAEM	United Nations Asia and Pacific Centre for Agricultural Engineering and Machinery
UNDP	United Nations Development Programme
UP	Uttar Pradesh
USD	US Dollar (1 USD= Approx. BDT 80)
VAT	Value Added Tax
WB	West Bengal/ World Bank

In Memory of
Mahabub Hossain- A Talent with Toil

Dr. Mahabub Hossain passed away in January 2016 while he was taking treatment at USA. He was the Director General of Bangladesh Institute of Development Studies. He was a Head of the Social Science Division of the International Rice Research Institute. Notwithstanding his fragile health condition, he finalised his chapter for this volume a few weeks before he left us forever. We are deeply indebted to him and pray for the salvation of his departed soul.

He was one of the influential agricultural economists and rural development practitioners of Bangladesh and Asia region. Mahabub Hossain conducted his pioneering farm survey in Phulpur, Mymensingh during 1973/74, which was the basis of his PhD thesis on farm size, tenancy and land productivity, submitted to the Cambridge University. Later on, Mahabub Hossain devoted his field research on foodgrain production, fertiliser policies, landlessness, labour employment, rural industries and public works. His IFDC survey in 1979-82 and IFPRI survey in 1982-83 resulted in his first publication of the book 'Green Revolution in Bangladesh' in 1989.

As the Director General of BIDS, Dr. Hossain proved to be a friendly administrator, efficient research manager and also good fund raiser to support research. He demonstrated his commitment to empirical field research and proved to be a prolific writer using empirical survey data. Mahabub Hossain was given the first gold medal award by the Bangladesh Agricultural Economists Association in recognition of his formidable contribution to research.

Dr. Hossain's widely referred 62 village Panel Household Survey conducted in 1988, 2000, 2004, 2008 and 2013 remains a data gold mine. He co-authored with Abdul

Bayes a number of books *Bish Gramer Golpo,* Leading Issues in Rural Development and *Tin Bigha Jomi,* all of which have rich empirical contents.

As the Executive Director of BRAC, he transformed his vast field experience into actions focusing on tenant farmers credit, food -nutrition nexus, crop and non-crop technology diffusion, hybrid seed production and so on. As a member of Bangladesh Agricultural University syndicate during 2009-2011 Dr. Hossain helped decision making towards academic development and proper allocation of funds by the university. Dr. Hossain did also contribute as a member of BARC governing body, chairman of Krishi Gobeshona Foundation (KGF) Technical Committee and a member of Krishi Gobeshona Endowment Trust.

Preface

This publication is a product of a regional workshop on Rural Mechanisation: Policy and Technology Lessons from Bangladesh and Other Asian Countries, held at the BRAC Centre Inn, Mahakhali, Dhaka on 7-8 March 2013. It was organised by BRAC and funded by IFPRI, CIMMYT and IRRI. Some funds were contributed by the Cereal Systems Initiative for South Asia (CSISA), which is jointly implemented by CIMMYT, IRRI and IFPRI, and is funded by the U.S. Agency for International Development (USAID) and the Bill & Melinda Gates Foundation. Additional support was provided by the CGIAR Research Programme on Policies, Institutions, and Markets. CIMMYT and IFPRI provided additional funds for meeting editorial and publication expenses. We remain greatly indebted to these organisations for their generous support.

The workshop sought to expand the discussions and debates that have been missing for more than two decades as well as gain a better understanding of rural and agricultural mechanisation situation within the region. The fourteen papers herein cover rural mechanisation in the related sectors of agriculture, energy, water, manufacturing, and policies that explain the spread of large and small scale technologies. In addition to all the thirteen presentations in the technical sessions of the workshop, we devote an introduction chapter to contextualise mechanisation processes in a historical, political and institutional setting and argue that Bangladesh is a special case.

We are thankful to all the paper contributors who worked hard to put their excellent pieces of work into final shape. Nearly 100 participants from the government, NGOs, universities, research organisations, development partners, private sector and media from home and abroad participated in the workshop. Thanks to the participants for their efforts and taking troubles to attend the workshop and making immense contributions.

The inaugural session of the two-day workshop was attended by Matia Chowdhury, the honourable Minister of Agriculture, Government of the People's Republic of Bangladesh, as the Chief Guest. Her presence in the workshop and expression of keen interests in farmers' need based machineries inspired us to publish this collection of papers. Dr. Atiur Rahman, Governor of Bangladesh Bank was the Chair, and Dr. Mahabub Hossain, Executive Director of BRAC, was the Special Guest. Professor Shamsul Alam, Member (GED) of the Planning Commission, Government of the People's Republic of Bangladesh and Dr. Md. Rafiqul Islam Mondal, Director General of Bangladesh Agricultural Research Institute, chaired the Technical Sessions. Professor M. A. Sattar Mandal, Member (Agriculture) of the Planning Commission, delivered the keynote presentation, while Dr. Stephen Biggs, Research Associate, SOAS, University of London, UK, gave an overview presentation on the nature and trend of rural mechanisation in Asian countries. Scott Justice, Agricultural Specialist of CIMMYT, Nepal, outlined the workshop programme and expected output. We express our immense gratitude to our valued guests for their valuable time and contributions.

There has been an unusual delay in publishing the workshop papers due to a number of unavoidable reasons, including getting revised versions of the papers, illness and then demise of Mahabub Hossain, who was deeply involved in the planning and organising the workshop. He also shared ideas about publishing the papers. We deeply acknowledge his contributions to the workshop.

Special thanks to Professor WMH Jaim and his colleagues at the BRAC- RED, who organised and managed the workshop including arrangement of international travels and accommodation. Thanks also to BRAC for providing logistic support and allowing us to use their venue for the workshop.

We are grateful to the Institute for Inclusive Finance and Development (InM) for arranging to publish the book within a very short time. Especially, we thank Dr. M.K. Mujeri, Executive Director of InM for keenly overseeing the publication, Sifat-E-Azam for her tenuous editorial support and Jabeer Sherazy for his nice cover design. We also appreciate the initial organisation of the manuscripts by Mr. Shamsul Alam. We however take the sole responsibility for any or all of the remaining errors including those in typing, spelling and reference citation systems. We also apologise for whatever overlaps and inconsistencies the readers find between chapters and sections.

Finally, we remain grateful to the Planning Commission, Government of the People's Republic of Bangladesh for giving inspiration to deliberate on a highly important topic like rural mechanisation, which has profound policy implications for Bangladesh and elsewhere in the South Asian region.

M. A. Sattar Mandal

Chapter 1

Bangladesh: A Special Case of Rural Mechanisation and Rural Development

M. A. Sattar Mandal, Stephen D. Biggs and Scott E. Justice

Introduction

In recent years, there has been a renewed interest in the role of agricultural and rural mechanisation in economic development. This chapter looks mainly at the spread of mechanisation in Bangladesh. Bangladesh has one of the most mechanised, yet least known about or understood rural economies of South Asia. In this brief introduction, we suggest that Bangladesh is a special case and that to understand how rural mechanisation played such a central role in rural development, it is important to reflect on the past history. We examine this proposition by reflecting on the processes from the 1970s to the present day. We see that mechanisation has been determined not only by national resource conditions, but also by the historical, political, institutional and economic context. What our reflections show is that while there has been great increases in agricultural production and other economic activities in rural areas, Bangladesh has not followed a path taken by other countries, and that the Punjabi model of the Green Revolution (often suggested as "the" Green Revolution path to follow) bears little resemblance to the policies and strategies taken by Bangladesh. An implication of this is that policies influencing rural industrialisation in individual countries and regions have to be specific to their current political, institutional and economic contexts. This is the lesson to be learnt from Bangladesh, rather than simplistic notions of the "transfer" of policies, technologies and institutions.

This introduction relies heavily on our experiences, rather than on detailed historical analysis. We hope, the readers will bear with us when they find in places, there are some overlaps between sections. We noticed that there are some differences in number of machines or equipment cited by different authors, which are due to year of reference or the sources being cited. Also, we only include references to illustrate a certain literature, rather than trying to make an academic judgement and cite accessible sources, or the work that might have had a major impact on influencing effective actors in the ongoing policy processes in Bangladesh.

We also apologise for the use of acronyms in this introduction and in other papers, but hope we have made things clear where necessary. However, this is part of the nature of ongoing policy discourse in Bangladesh and internationally, and to translate all this would take more time than we have available.

Recent Economic Growth

Bangladesh has achieved an impressive average GDP growth rate of 6.3 percent during 2011- 2015, which has surpassed growth rates in India, Thailand, Indonesia and other developing countries and is only a little behind China with 7.8 percent growth (Planning Commission, 2015). It has a target to achieve middle income status with a per capita income rise to US$2000 by 2021 from US$1190 in 2014, together with notable improvements in important human development indicators. The country's economy is also diversifying at a reasonable pace with readymade garments and shrimp as the top export sectors. Annual remittance income of about US$ 15 billion from migrant labour accounts for about a half of the current foreign exchange reserve and this meets over one third of import bills in recent years. Both export and import sectors are quite diversified and have grown by 18.5 and 14.3 percent, respectively, in the last five years (Ministry of Finance, 2016).

The rate of growth of agricultural gross domestic product has been around 3.5 percent with clear signs of reduced instability in rice production, decreased rice import dependency, increased food security and significant poverty reduction. Although rice still occupies about three fourths of gross cropped area and about 40 percent of total food value added (FPMU, 2015), agricultural diversification has increased along with crop intensification. The rapid growth of the shrimp industry is just one of the examples of agricultural/rural diversification. Shift to high value agriculture i.e., fish pond or orchard is another recent phenomenon.

Agriculture's share of employment decreased from 62 percent in 2000 to 55 percent in 2010, while in contrast rural non-farm (RNF) employment increased from 38 percent to 45 percent during the same period. When it comes to share of income at the household level, relative share of agriculture dropped a little from 49.9 percent in 2000 to 47.8 percent in 2010 and RNF increased modestly from 50.1 percent to 52.2 percent over the same period (World Bank, 2016).

What is intriguing is the diversity of RNF activities, which are basically led by growth in crop and non-crop agriculture, in a context of micro credit, rural remittances, growth of road connectivity and rural electricity and fossil fuel supplies. The RNF activities can be defined as those that are farm oriented and those that are beyond farm. The farm oriented enterprises include rural manufacturing and trading of farm inputs, machinery, equipment and spare parts, poultry and fish feeds, veterinary services, rural mechanic services, etc., while the "other' category" of RNF covers quite large and diverse functions i.e., rural construction, housing, masonry, carpentry, agro-processing, shop keeping, tailoring, rural transport, rural restaurant, food vending, etc.. Both these broad categories of RNF activities can be labeled as "parts" of the process of rural industrialisation, some of which are "dynamic" components involving more skilled labour with higher wages and sophisticated capital goods, while the "residual" segments that use low wage unskilled labour and small equipment are dying out in competition with dynamic ones (Mandal, 2003).

Political History

The war of liberation in 1971 with its drive to establishing a poverty and hunger free self-reliant economy was a unique political motivation for firmly instilling Bengali nationalism. The independence movement brought people together around language first and then aspirations for autonomy and finally self- rule; it focused attention on rural areas where most of the then 75 million people lived and deepened feelings of self- reliance to address chronic food deficits. Average annual food grain import stood at 1.1 million tons during 1966-70, went up to 1.5 million tons in 1969-70, the year preceding the war of liberation, which actually rose to more than 2.5 million tons in 1972 and 1973 in the aftermath of liberation war (Planning Commission, 1973). To meet the food deficit and attain food grain self- sufficiency, the Government promoted the spread of basic inputs, such as seed-fertiliser-water and supporting technology to achieve the over arching goals of the new government as outlined in the First Five Year Plan. This goal for increasing food production was pronounced in the historic speech by then Prime Minister at the Bangladesh Agricultural University, Mymensingh on 13 February 1973 where he stressed the need for technological innovation not only for rice but also for fish, meat, milk, and vegetables. Referring to the redirected focus of his government on rural development, Bangabandhu Sheikh Mujibur Rahman, the Father of the Nation, called upon the students and teachers of the university to engage in practical works in villages to bring about modernisation of agriculture. This was a significant political commitment to broad based rural economic development.

The new government of Bangladesh imbued with four basic principles of democracy, nationalism, socialism, and secularism, quickly adopted a number of radical decisions towards agricultural change e.g., exemption of land taxes for holdings up to 25 *bighas (*one bigha equals one third of an acre*)* also fixing maximum ceilings on land holdings and redistribution of excess land to landless households, and mobilisation of labour for development work. While the procurement and spread of relevant new technologies were put at the centre of agricultural and rural development policy debates, liberal credit support and subsidies on the relatively expensive equipment, such as irrigation tube wells, tractors, tillers, fertilisers was provided, with plans for their gradual reduction over the years. Significantly, in Bangladesh's case, these subsidies were reduced gradually.

The use of tractors and power tillers during pre- liberation period remained mainly confined to *haor* (low lying flood prone) areas, development estates and government seed farms, and used more for hauling than for tilling. In the post-liberation, distribution of these equipment concentrated on facilitating ploughing and land preparation activities to recover from the loss of draft animals in the 1970 cyclone affected areas in the southern regions and then to gear up production in other districts.

The First Five Year Plan reports distribution of a fleet of 162 tractors and 562 tillers operating in cyclone affected areas; while in the border districts, where a large number of bullocks and draft animals were killed by the Pakistani army during the liberation war, 180 tractors and 648 power tillers were distributed there. The plan also underscored the immediate need for a pilot project in three locations to determine the realistic size of a mechanisation programme in different areas, improve machine repair and maintenance facilities, support farm management cost and return studies and evolve procedures for tractors/ tillers hire rental services. The importance of other implements like rotary weeders, pedal threshers, and hand sprayers to the farmers was highlighted and their local large scale manufacturing was encouraged and experimenting with rice transplanter, spike toothed harrow and small paddy driers was emphasised, while modest subsidies for these expensive machineries were also proposed. The First Five Year Plan also called upon the Agricultural Engineering section of the then Agricultural Department and the Faculty of Agricultural Engineering at the Bangladesh Agricultural University (BAU), Mymensingh to improve the design of traditional farm implements used for harvesting, weeding, levelling, raking and crop cutting. To encourage manufacturing firms and cottage industries to scale up production of this type of equipment, credit support of about Taka 10 million (approx. 1 million USD) was provided in the first plan (Planning Commission, 1973; pp. 178-181).

To understand rural mechanisation/industrialisation processes in Bangladesh, another dimension is the history of the jute industry of Bengal during British period and then also during the Pakistan period. Jute, popularly known as the "Golden fibre of Bengal", used to be grown as cash crop mainly to feed the jute industries in Dundee, Scotland. After the partition of Bengal in 1947, several groups of West Pakistani families started jute businesses by setting up several jute mills in Narayanganj of then East Pakistan, the most significant ones were Adamjees, Bawanis, Ispahanis, and Dauds. After the liberation of Bangladesh in 1971, when the Pakistani owners left, all the jute mills abandoned by them were nationalised and put under the control of state run Bangladesh Jute mills Corporation (BJMC). There are now altogether 27 government jute mills under BJMC and a far larger number of 80 jute mills in the private sector represented by Bangladesh Jute Spinners Association (BJSA). Bangladesh currently produces about 2 million tons of raw jute annually. Jute being a highly labour intensive crop, the whole range of activities involving cultivation, harvesting, retting, extracting fibre, drying, grading, packaging, baling, handling, jute handicrafts- all constitute very important elements of rural development at large.

Export of 1.2 million tons of raw jute and jute goods from East Pakistan earned about 74 percent of total export earning of Taka 3.69 billion in 1969-70 (Planning Commission, 1973) and remittances of this trade in agricultural goods to East Pakistan was an element in factors underlying independence. Jute export earnings from East Pakistan not being used for the development of this province was a major source of dispute, leading to the proposition of "two economy theory", which manifested in growing disparity between the two wings of Pakistan.

Engineering Capacity and On-going Engineering Contestations

Bangladesh has a long history of industrialisation around Chittagong port, and also around Saidpur in the north for railway engineering; trades in jute, tea, hides & skin had led to the establishment of an engineering profession. As regards agricultural mechanisation, Bangladesh Agricultural Development Corporation (BADC) established a separate mechanisation wing as per Pakistan Farm mechanisation Committee Report, started a 4-wheel tractor as well as a 2-wheel walking type power tiller (also known as 2-wheel tractor) programme side by side with the promotion of IR-8 rice cultivation. And very importantly, besides promotion of low- lift power pump irrigation, BADC also pioneered mechanisation of groundwater irrigation through installation of tubewells throughout the country. A machinery Standardisation & Testing Sub-committee was formed and various test beds established at the Bangladesh Agricultural Institute (BAI) campus at Shere Bangla Nagar, Dhaka, which was later shifted to the current Bangladesh Agricultural Research Institute (BARI) campus to strengthen agricultural engineering research. The mechanisation drive was subsequently anchored within the academy with the establishment of the Faculty of Agricultural Engineering & Technology at BAU in 1964 and the establishment of the Bureau of Research & Testing at the Farm Power & Machinery Department of this faculty in early 1980s for field testing of engines. The BARI testing bed was used for overall engine testing. The Mechanical Engineering department of the Bangladesh University of Engineering and Technology (BUET) was also involved later on. Senior members of the agricultural engineering faculty were involved in field testing of tractors and power tiller engines; although BADC specified testing certificates about engine brands were necessary for importing engines. In the early days of the 1970s and 1980s, the most common types of 4-wheel tractors were Massey Ferguson, International, Belarus; pumps sets were Kirloskar, Ruston and Deutz, and 2- wheel power tillers included Yanmar and Kubota. This has changed gradually over the years. Now the most common brands of four-wheel tractors include Tafe, Mahindra, Sonalika, Eicher, Deutz far etc. The most popular engines imported these days included Yanmar, Duetz, Semens, Cummins, Perkins, Lister, Kirlosker, Dongfeng, and Saifeng. Most of rice huller machines are made in Bangladesh and India. Significantly from the earliest days of the 1980s, Bangladeshi traders explored markets for new types of engines and equipment and imported products they thought relevant. While Chinese engines and associated equipment now dominate the rural landscape, this did not come about as a result of major Chinese aid programmes for the promotion of this equipment, nor from local government programmes for specific types of "south-south" technology. It was good enough, robust enough and cheap enough for Bangladesh conditions.

Challenges to predominantly engineering solutions to rural development came also from the involvement of some donors in the 1970s (e.g. Ford Foundation and Agricultural Development Council). They funded institutional building programmes and research projects in economics and social sciences; much of which was directed at rural development. Part of the history of agricultural mechanisation relates to the spread of manual pump irrigation (MOSTI). Hand pumps and treadle pumps were introduced after independence (Hannah, 1976; Biggs *et al.*, 1978; Orr *et al.,* 1991) to counter increases in food prices in 1974 when food shortage was conspicuous. These manual pumps spread in remote char land areas by the households using mostly family labour. The hand pumps in particular involved drudgery and arduous human efforts leading to exploitation of cheap labour including poor women (Mandal, 1978). These were gradually replaced with the introduction of relatively inexpensive small horse power diesel engine that powered pumps during the 80s and 90s. Besides the immediate contribution of hand pumps and treadle pumps to rice production by the poor farmers, their installation and maintenance operations led to the growth of rural mechanic services and spare parts manufacturing at the local level.

An industrial hub for machine manufacturing was established at Bogra in the late 1960s,. Subsequently, similar machinery manufacturing started in Sylhet, Jessore, and Kushtia (see chapter 3 for more details). The growth of power threshers manufacturing in Kishoregonj has been quite spectacular in the last decade. Development of wheat threshers from BARI with various agro-machinery manufacturers like Rahman Engineering at Bheramara, and Janata Engineering at Jessore, brought nearly 100% mechanised wheat threshing to Bangladesh by the late 1990s. Rural machinery is generally characterised by the hazardous working conditions of labourers. In the Bangladesh context, this issue was discussed in a widely circulated newsletter, Agricultural Development Agencies in Bangladesh (ADAB) News (Clay, 1978). Currently, the entire threshing of rice is done by mechanical threshers (with their open – uncovered drive belts and pulleys) produced by numerous local manufacturers (see chapter 7 for the status of machinery manufacturing business).

Bangladesh also has a long history of flood control, embankment and water management by the Bangladesh Water Development Board (BWDB), which has a dominant engineering department. And some of their engineering interventions had been effectively challenged and significant changes made after independence (see Biggs *et al.*, 1978 for a policy discussion of underutilised irrigation potential). Perhaps one of the most well-known challenges to agricultural engineers came in the late 1980s when the powerful machinery standardisation committee was abolished overnight, so that "good enough" Chinese engines could be imported to address the loss of cattle due to natural calamities. Contestation over "choice of techniques" continues, where engineering solutions miss social and economic considerations (e.g. poldering, sluice gate, money spent on large deep tube well and surface irrigation schemes where shallow tube well and small pumps work better are some of the examples). The point we are making here is that this type of contestation has been central to policy analysis in Bangladesh, and it is important to note that the debates are kept alive and open. The widespread arsenic poisoning, as a result of groundwater development is an example.

The mechanisation process was propelled by a number of other factors as well, which included the exodus of mechanics from BADC with golden handshakes in the government privatisation programme in the early 1990s. Many of these retired staff took up jobs in the private sectors, started manufacturing units, consultancies and some joined the staff of training institutions. The policy commitment and funding of vocational training schools and private mechanic training institutes for "hands on" training has been very important in the Bangladesh history. The CARITAS funded Mirpur Agricultural Workshop and Training School (MAWTs), Bangladesh- German Technical Training Centre, and Bangladesh Industrial and Technical Assistance Centre (BITAC) are some of the notable initiatives. In the early 2000s, Department of Fund for International Development (DFID) funded a Research and Extension in Farm Power Issues (REFPI) project at BAU that provided technical support to private manufacturers and workshops to upscale their business. This contributed significantly to the expansion of farm mechanisation as well as engineering capacity building at Bangladesh Agricultural University (BAU) since late 1990s (details are given in chapter 8). What is significant about this engineering institutional history is the long term commitment, that started in the 1970s, to institutional building in vocational training, applied engineering, keeping the policy debates open, and the Planning Commission encouraging Bangladeshi importers look for suitable equipment abroad.

Agronomy and Natural Resource Conditions

Population density, fertile soil and deltas, monsoon economy and the distribution of land and other assets also shaped the cropping system/ farming system technologies. Since the early 1970s, the rich extensive documentation of soils, climate, hydrology and land use in different agro-ecological zones in Bangladesh informed academic as well as policy circles to pursue pragmatic programmes towards agricultural and rural development. A prominent one was in the 1970s for accelerated cereals production with HYV rice and wheat (Brammer, 1978, 1980, 1987, 1997 and Orr *et al.*, 1990).

The riverine settings of the country meant that river transport of people and goods was a major rural industry with boats using sails and manual labour to pull loaded boats and barges back up the rivers. Small engines imported from China duty free in the name of agricultural pump sets soon "jumped" to powering river transport in the early 1980s and almost overnight, the familiar, much patched sails were no longer seen. The river networks also favoured surface water irrigation by manual methods as well as engine powered low- lift pumps for growing high yielding rice in the dry winter months, which provided a boost to accelerating rice production since the sixties.

Mechanisation allowed ground water irrigation using fallow dry land that needed engineering and social science interventions. This included installation of deep tube wells and shallow tube wells for irrigating *boro* rice in medium high and low lands with clay and loam soils in relatively favourable locations. Lands with sandy light soils and uneven topography or with low ground water aquifers could not attract investment in tube wells for rice irrigation.

The widespread development and promotion of knowledge of locally relevant agronomy and rural engineering field experience has also been an important feature in agricultural development. For example, the International NGO, the Mennonite Central Committee, mainly made up in country practical agronomists, used its extensive Bangladeshi experience for the development and promotion of smaller scale ground water technology. Another example of a method for promoting relevant agronomy information was the initiation of the ADAB News. In the 1970s, a mixture of government officials, Non-Government Organisations (NGOs), researchers and academics started the News letter, which discontinued some years ago. During these early years, publication of two pioneering journals from BAU –the Bangladesh Journal of

Agricultural Sciences, and the Bangladesh Journal of Agricultural Economics- started, both of which contributed to technology policy discussion based on first hand knowledge from field researches.

Broader Institutional Context of Agricultural Development

In pursuance of priorities earmarked in the first Five Year Plan of Bangladesh (1973-78) for a strong national agricultural research system, the Bangladesh Agricultural Research Council (BARC) was set up in 1973 drawing on some of the best rated agricultural scientists. This created opportunities for the first time to mainstream agricultural research into the planning process by the country's Planning Commission, that was set up in 1972 with the best known economists as its core members. Prior to this, the Bangladesh Rice Research Institute (BRRI) was established in 1970/71 and got considerable donor support from the beginning. Then in 1976, the Bangladesh Agricultural Research Institute (BARI) was established in the same vicinity as BRRI at Joydebpur, Gazipur with the mandate of conducting research on all crops, except rice, jute, and sugar cane. The creation of separate agricultural engineering divisions in BRRI, BARC, and BARI gave a further boost to pioneer R & D in agricultural mechanisation. As a continuation of streamlining the National Agricultural Research System (NARS), more commodity based research institutes were also created separately for livestock- Bangladesh Livestock Research Institute (BLRI), fisheries- Bangladesh Fisheries Research Institute (BFRI), sugarcane - Bangladesh Sugarcane Research Institute (BSRI), jute- Bangladesh Jute Research Institute (BJRI), tea- Bangladesh Tea Research Institute (BTRI), and for wheat- Bangladesh Wheat Research Centre (BWRC) in the 1980s and 1990s. This was a very significant investment in knowledge and research capacity building for rural based economic development.

Because the population densities of Bangladesh are so high, and the population fairly evenly distributed in the country, most of the agricultural research institutions and universities were, by many criteria very accessible and well connected, and have had on-farm research outfits. This meant that staffs of those institutions were frequently involved in planning, policy and the implementation of projects. They also carried out research and teaching in their own fields of interest.

From the 1960s, the Rural Development Academy at Comilla conducted social experiments - social engineering –for rural development following a two- tier cooperative model. The Academy was renamed as the Bangladesh Academy for Rural Development (BARD) after independence. The cooperative model developed, widely known as the Comilla Model, where large- scale machines (e.g., four- wheel tractors) were promoted through cooperatives to gain scale economies - small- scale machines were not a central consideration. The Comilla Model led to corporate captive capital, "cooperative capitalism" (Khan, 1979; Lewis, 1996) (later came to be known as "elite capture"). The nationwide spread of the Comilla cooperative approach also received criticisms because it received heavy subsidies and showed very little evidence of being an efficient or equitable "green revolution" strategy (Bose, 1974). While market intuitions for capital goods services were widespread (for ploughing, water, harvesting, rural transport, river transport), these were not a major concern of the Academy.

A second Rural Development Academy (RDA) came into being in Bogra in the 1970s and concentrated more on small-scale rural mechanisation i.e., community water supply, small machinery promotion and training often involving private sector manufacturing.

Along with the government, the NGO sector has played an important role in rural economic development since the beginning of Bangladesh. The Bangladesh Rural Advancement Committee (BRAC) was established as part of the rehabilitation and reconstruction programme of the new country (Abed *et al.*, 1984). Then came Grameen Bank with micro financing. The NGOs provided credit, training and technology support to landless and marginal farmers for machine hiring and irrigation services e.g., landless irrigation by Proshika and Grameen Bank in 1980s, and pond fishery, dairy, seed production, etc. by BRAC since 1980s. Another major local NGO Proshika's experiment with irrigation water selling not only brought a productive asset like shallow tube well to landless groups but also it combined social mobilisation with income earning opportunities (Wood and Palmer- Jones, 1991). Although these irrigation experiments and programmes were abandoned later on, many of the landless entrepreneurs gained first hand machine orientation to take up STW water selling on their own.

With independence, international organisations made grants and contact with the new state bureaucratic structure in new ways. For example, Ford Foundation made grants drawn up by local institutions and approved of by the Planning Commission direct to Bangladesh institutions, rather than to international institutions for the benefit of Bangladesh. Examples were grants to BRRI instead to IRRI for the benefit of BRRI. Significant grants came from other countries, such as Australia for the Sugarcane Research and Training Institute (SRTI), Japan for the Citrus and Vegetable Research Centre of BARI, and Great Britain for the Bangladesh Tea Research Institute (BTRI) (Badruddoza, 2001). After independence, there were many highly trained people in many senior jobs, both in Government and in NGOs. This helped lead to "donors" and/or people in government agencies not domineering aid debates and the content and practice of projects.

In the early 1970s, international agencies i.e., Ford Foundation and the Agricultural Development Council gave substantial support to institutional development, such as training programmes and the funding of social science research by local people. Some of this looked at the underpinning issues of rural mechanisation. This included quick and clean surveys by groups from government, NGO and academic institutions visiting and learning from the multitude of formal and informal experiments taking place in rural areas. In the early years, these concentrated on the spread of groundwater irrigation (Biswas and Mandal, 1982; Mandal, 1993; Hamid, 1977; Yunus, 1977). This extended to research on appropriate technology in case of mechanisation of land preparation (Gill, 1979/80) and also on issues of draft power shortage (Jabbar, 1980). This applied social science research was followed with DFID sponsoring a Research and Extension in Farm Power Issues project at BAU in the early 2000s and International Centre for Maize and Wheat Research (CIMMYT) and Food and Agriculture Organisation (FAO) sponsored promotion of seeding and harvesting attachments for two-wheel tractors that gave a concerted effort to develop local machinery manufacturers and traders. The demonstrating and promoting of farm machineries, such as maize sheller, wheat thresher, and especially and more recently rice thresher are key outcomes. Consultative Group on International Agricultural Research (CGIAR) system has participated in promoting agricultural mechanisation more recently; Cereal Systems Initiatives for South Asia – Mechanisation & Irrigation (CSISA- MI) of CIMMYT and CSISA- BD in collaboration with BARI, BRRI and DAE are engaged in pursuing appropriate- scale machinery for conservation agriculture e.g., power tiller operated bed planters, strip till drills, etc. (Krupnik *et al.*, 2013).

Academic Discourses

Policies since independence have been informed by vibrant academic discourses (e.g., research, rural field studies, seminars, workshops, village surveys). For example, we have mentioned the special purpose surveys in the

1970s sponsored by the Ministry of Local Government and Rural Development. Some of the village level studies that contributed to policy debates during the early years of independence include those on locally initiated self- reliant programmes by Rajshahi University faculty, cooperative farming experiment by BAU, Mymensingh, and the locally sponsored development series by Chittagong University (Hamid *et al*., 1976; Husain, 1973; Yunus and Latifee, 1975; Yunus and Islam, 1975). The other studies in the Rajshahi University series include Ganamilan, series 1; Swanirvar Kuzipukur, series 2; Swanirvar Karmasuchi- Bogra Azizul Haque College, series 3; and Christian Service Society- Dacope, series 5. These studies were also supplemented with focused field reports on rural development by experts from abroad (e.g., observations from fields provided important insights for short as well as medium and long term steps towards rural development (Dumont, R., 1973). To inform the Planning Commission immediately after the independence, the Directorate of Agriculture (Extension and Management) with initiatives from FAO and support from A/D/C initiated a field survey and produced the first empirical data on landlessness and land tenure. An issue of central policy implications in the 1970s (BARC, 1978). FAO/ UNDP subsequently initiated action research project to support small farmers and landless labourers, which involved village surveys, workshop discussions and recommendations towards group lending for income generation (Alam, 1979). It is possible now that the ownership of rural capital goods and associated market institutions for access to capital goods services may be as if not more important for economic efficiency and equity policy criteria as the ownership of agricultural land.

The 62- village surveys of Bangladesh Institute of Development Studies (BIDS) contributed immensely to improve understanding of agriculture and social changes, however, interestingly this and other national sample surveys and other surveys have little on rural mechanisation. The special purpose survey for this mechanisation workshop was carried out because earlier surveys had not looked at rural mechanisation issues (See chapter 6 for more details). BADC and BIDS field studies on capacity under-utilisation of DTWs and LLPs were pioneering works in the 1970s to draw attention to the inappropriateness of these technologies pushed through by earlier governments with heavy subsidies (Alam, 1974; 1974, Biggs *et al*., 1978 (Interestingly, one of the first surveys on the utilisation of DTW was done by BADC, and more formal surveys followed that). The field studies on the socio-economics of STWs, DTWs and LLPs under IDA credit were important contributions to policy decisions in the early

1980s when irrigation management was largely controlled by the public sector (Hamid *et al*., 1982). Subsequently, performance of irrigation tube wells was compared and contrasted between different management approaches (IWM, 1985; Palmer-Jones and Mandal, 1987). Later on, large scale field studies in the late eighties and early nineties analysed the growing irrigation water market and influenced a major policy shift towards a far greater role for the private sector (IWM, 1986; IIMI, 1996; Palmer-Jones, 2001). Key to all these policy changes was the cost-effective field work and involvement of senior researchers in the field work. This illustrates an important long term tradition in the academy's work in the area of rural mechanisation. A recent reflection on the contemporary scenarios of rural mechanisation in the context of Bangladesh and Nepal is available in Justice and Biggs (2013).The continuing vibrancy of the academic literature in Bangladesh is illustrated by a recent article on rural mechanisation where large scale census household data is now being examined for its rural mechanisation policy implications (Mottaleb *et al*., 2016).

The Governments' high confidence in the academy was evident in putting applied academics in the first Planning Commission. The overriding role of the Planning Commission influenced political decisions based on empiricism; vibrancies of academic engagements helped shape the preparation of a development road map i.e., the First Five year Plan in 1973 by the top economists of the day and quite a number of bright professionals from universities (many of them were actively involved in the liberation movement). A similar initiative was undertaken by the Planning Commission jointly with European Commission in organising a high level policy workshop in 1988, which gathered eminent intellectuals and bureaucrats and produced medium and long term food strategies for Bangladesh (Planning Commission, 1989). These documents addressed issues on creating provisions for rural capital formation through promoting mechanised irrigation and tillage, appropriate technology and HYV rice expansion in the backdrop of draft power shortage and achieving productivity gains. In the late 1980s, dropping experimentation with promoting four-wheel tractors with subsidies and allowing the imports of Chinese made two-wheel tractors (power tillers) encouraged patterns of rural mechanisation relevant to Bangladesh. The government continued with its gradual reduction of subsidy on fertilisers as outlined in the First Five Year Plan. Despite deviations at times, the public sector by and large played a proactive and effective instrumental role in managing prices, institutions and lobby groups dealing with import, distribution, repair, and manufacturing of some machines.

Infrastructure

Extensive road network, growth of rural towns, mechanised boats, mobile phones, rural electrification- all facilitated rapid expansion of mechanisation in agricultural production, rural transport, rural construction and rural agro-processing activities. Also, unprecedented improvement in road connectivity and digital communication facilitated farmer- farmer (rural entrepreneur-rural entrepreneur) technology transfer and sector to sector transfer (e.g., Chinese engines to boats, or shifting of two-wheel tractors and four-wheel tractors between agriculture and transport sectors, which is common in Bangladesh). It may be that in some countries some time agricultural tractors are only used for tillage, but in Bangladesh "agricultural" tractors have always been used for multiple purposes, and there have been active markets in equipment services. All of this has happened because of the high population density and also to increase returns to investment in "expensive" rural capital goods. To some extent Bangladesh has never had a conventional separation of "rural " and " urban", "agriculture", "industry" and "services". And with very high road density and with increasing rural electrification, it is indeed a changing rural-urban continuum.

Energy and Energy Policy

Another contextual feature for understanding agricultural and rural economic growth in Bangladesh is the importance of the Bangladesh gas deposits that has been a major source of energy and urea fertiliser. Earlier decisions were made to use gas locally, and use it for local industrial, transport, and agricultural development, rather than export it. Total proven plus probable gas reserve remaining amounts to 14.09 TCF, while total consumption of gas has been 13.03 TCF up to June 2015 (Planning Commission, 2015).

A crucial policy "choice of technique" decision was taken when Bangladesh from the 1970s promoted diesel run irrigation pumps (low-lift pumps and tube wells), two-wheel tractors and four- wheel tractors, power threshers and power tiller operated implements. Although some provisions for electric powered irrigation based on a public sector grid was also made, it was very small . As a part of renewable energy policy, solar energy is being promoted for powering irrigation pumps (see chapter 12). Besides, biogas is being used for domestic consumption.

Although relatively ensured supply and liberal use of gas has boosted the country's economy so far, gaps between daily production and demand and current prices are apparent. This prompts rational energy policy with respect to gas allocation, energy subsidy and pricing, domestic coal utilisation and energy import. In the early years, these energy policies were not a major focus of the rural mechanisation debates, but now are taking on central importance.

Conclusions

Behind every "Green Revolution", there is a pattern of rural mechanisation that facilitated agrarian change and rural development.

1) Many discussions of agricultural development have been based on the production of major food crops, such as rice, wheat, and maize, and the improvement of high yielding varieties. While major increases in crop production have taken place in Bangladesh, we suggest that to understand how and why this took place, we have to look at the processes and patterns of rural mechanisation and rural industrialisation that have been taking place for so many years in rural areas. A lesson from Bangladesh is that its "green revolution" cannot be separated out from a broader framework of multi-sectorial rural economic growth, and increasing crop production and productivity was just one element of that.

2) While breeding in plant, livestock, fisheries, etc. have led to changes in the potential uses of crop, etc., it is the particular local pattern of rural mechanisation that enabled this genetic material to express itself. However, this total dependence on a locally specific pattern of rural mechanisation is often overlooked in the literature.

3) The Punjabi "Green Revolution" model of subsidised energy inputs and large –scale mechanisation was not followed in Bangladesh. Small-scale mechanisation took place successfully in the prevailing small- farm dominated agrarian structure and largely informal economy. Market institutions for equipment services promoted since the 1970s.

4) Simplistic arguments that there is just one pattern of agricultural and rural mechanisation that leads inevitably to the displacement and unemployment of labour proved wrong in Bangladesh.

5) Rural entrepreneurs in Bangladesh came from diverse backgrounds- farmers, mechanic, traders, remittance earners who were neither from large land owner groups nor from rural powerful or higher social class groups as many might have expected.

6) Surplus generated from farm and non-farm sectors, in many cases,

reinforced by remittances from within and outside the country, has been often reinvested in rural mechanisation and rural industries (others may call them small and medium enterprises (SMEs); prominent ones include grain milling, metal workshop, shop keeping, restaurants, machine repair shop, housing and construction, saw mill and carpentry, commercial and home yard poultry, and poultry processing, pond fishery, animal feed industry, small- scale dairy, etc.

And in the Future

For sustaining agricultural mechanisation and processes of rural development, there are research needs in areas, such as mechanisation and gender, mechanisation to reduce drudgery in smaller scale rural enterprises, machinery safety, economics of rural mechanisation in changing food system and cropping patterns, diversification of rural enterprises, upgrading academic curricula and course contents, short and long term vocational courses, etc.

Other areas that need more attention are 1) policy coordination between "siloes" in international banks (e.g., Asian Development Bank, World Bank), and in government bureaucracies; 2) spread of mechanisation for non-rice crops e.g. vegetables and fruits, and also non-crop agriculture e.g. aquaculture, animal feeding, milking machines for small-scale dairy, etc. 3) measures to encourage responsible private sector actors involved in machinery manufacturing, import and distribution, and in backstopping local service providers; 4) getting appropriate technology and fiscal measures to encourage nutrition sensitive rice processing; and 5) promoting use of solar energy for agriculture and rural development.

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Chapter 2

Rural and Agricultural Mechanisation: A History of the Spread of Small Engines in Selected Asian Countries[1]

Stephen Biggs and Scott Justice

Introduction

In the past few years, patterns of rural mechanisation have taken on a new significance with concerns about, among other issues, future global food supplies, food wastage and debates around *land grabs*,[2] food security, rural employment, energy generation and use, and water scarcity. These concerns encompass the broader questions of whether, and under what circumstances, rural development should be seen as an important development goal.

When discussions of future global food supplies are presented in the press, they are often accompanied by pictures of large-scale equipment, such as powerful four-wheel tractors (4WTs), large combine harvesters (like aircraft in formation), and large-scale irrigation schemes. In land grab situations, if the land acquisitions are for agricultural production, there is generally a large-scale,

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[1] This paper was published as IFPRI Discussion Paper 01443, May 2015 by the Development Strategy and Governance Division of the International Food Policy Research Institute, Washington DC, USA. The first version of the paper was presented at the workshop "Rural Mechanisation: Policy and Technology Lessons from Bangladesh and other Asian Countries," held in March 7–8, 2013, at the BRAC Centre Inn, Dhaka. It formed the basis for the keynote presentation at the conference "Mechanisation and Agricultural Transformation in Asia and Africa: Sharing Development Experiences", June 18–19, 2014, co-organised by International Food Policy Research Institute (IFPRI) and the National School of Development at Peking University in Beijing, China. We would like to acknowledge financial support from the CGIAR Research Programme on Policies, Institutions, and Markets, led by IFPRI and the United States Agency for International Development which sponsored travel to the conference. We would like to thank Xinshen Diao and other conference participants for providing helpful comments that further improved the paper. We also would like to thank the editorial assistance of Dr. Robin Heath and an anonymous reviewer and copy editor. This paper has not gone through IFPRI's standard peer-review procedure. The opinions expressed here belong to the authors, and do not necessarily reflect those of PIM, IFPRI, or CGIAR. Any and all errors are the sole responsibility of the authors.

[2] These issues are highlighted for South Asia by Vokes and Goletti (2013).

highly mechanised agricultural production, processing, and marketing process involved. Articles and pictures of rural economies where smaller-scale mechanisation plays a central part in increasing agricultural and other rural economic activities are seldom seen.

Despite the media's presentation, during the past 60 years smaller-scale equipment has been spreading throughout much of East and South Asia. Many Green Revolutions have come about not as a result of the spread of larger 4WT and large combine harvesters but as a result of the spread of smaller-scale equipments, such as two-wheel tractors (2WT), shallow tube wells, smaller-scale low-lift pumps, small engines on boats, and artisan-made three- and four-wheel rural transport vehicles. Whereas much attention has been given to the role of high-yielding crop varieties in past Green Revolutions, little has been paid to the equally important role of engineering equipment for timely land preparation and sowing, careful water management, harvesting, threshing, and the local processing, transporting, and marketing of agricultural and other rural products, all of which lead to productivity gains and increases in cropping intensification. And while use of machinery in farming does not directly lead to increase in yields, it can facilitate the intensification of production through quicker turnaround times, careful and timely use of water, plant protection, harvesting, and so forth, which do increase yields, reduce losses, and often reduce drudgery.

Most past Asian Green Revolutions relied on cheap energy policies for the agricultural sector through subsidised fossil fuels, electricity, and urea. In addition, agricultural machinery was often subsidised with capital grants and low-interest loans. The future for many South Asian countries will depend on a more careful investigation of the short- and long-term outcomes of alternative patterns of rural mechanisation. The purpose of this paper is to examine historical patterns of smaller-scale rural mechanisation in South Asia to draw lessons for current and future policy.

In the 1970s and 1980s, there were major *choice of technique* policy debates concerning rural mechanisation, but by the 1990s, the debates had nearly ceased. Since the 1970s many patterns of rural mechanisation have taken place in different parts of the world. In the past, the choices of techniques have been limited to commercially available, Western-manufactured, large-scale machinery. Paradoxically, after the decline of the debates, the choice of techniques greatly expanded in the origins and numbers of manufacturers and expanded in scale to commercial small-scale machinery. In this paper, we focus on the spread of these commercial smaller-scale agro-machinery and rural equipments, such as 2WTs, low-lift pumps, pump sets for shallow tube wells, hullers and mills, and even riverboats, rural-manufactured three- wheel rickshaws, and four-wheel country trucks, mostly powered by single-cylinder diesel and petrol engines[3] (up to 24 horsepower).

We use the term *rural mechanisation* rather than *agricultural mechanisation* because it is only rarely that one can separate agricultural mechanisation from other rural economic activities. Paradoxically, the term *tractor* conjures in many people's minds a tractor that is used for agricultural uses. However, in many parts of Asia, tractors and especially 2WTs and 4WTs are often used as much for transportation purposes as for agricultural purposes.

Much of our paper will be an illustration rather than a detailed review for a number of reasons. First, our purpose is to open up the policy debate on rural mechanisation rather than examine detailed technical issues. Although technical engineering details are important, so too is historical, economic, and social research information, and it is this overarching policy analysis that is our focus. Second, a comprehensive review is beyond the resources we have at our disposal. Finally, country, local, and regional analysis involving local expertise is probably the most critical policy issue at the moment.

We concentrate on engineering equipment because analysis of engineering technologies appears to have been neglected in past agricultural technology policy debates in favour of plant science. There are of course many situations in which the interaction of genetic changes in crop varieties and engineering technology have played complementary roles, for example, shorter-season crops and equipment needed to decrease turnaround times necessary for intensification (Grandstaff *et al.,* 2008). However, attention has often then been given to the importance of the improved seeds rather than to the engineering technologies that have enabled the intensification and economic use of land, water, soils, timeliness of operations, and so forth.

On the whole, we do not look at larger-scale equipment or its interaction with smaller-scale equipment as it is beyond the scope of this paper. We also avoid

[3] Single-cylinder internal combustion engines in the West are normally petrol (gasoline) powered as these engines are lighter, are smaller in size, and cost less compared to similar horsepower diesel engines. Historically, in much of Asia, countries have put higher taxes on petrol as it was considered that petrol engines were found in more luxury consumer vehicles. Diesel engines were found more in transport and industry vehicles as well as agricultural tractors. Though diesel engines cost 25 percent or more than petrol engines, the cost of diesel fuel is 10–20 percent lower. When operating costs outweigh capital cost farmers and rural service providers prefer diesel engines.

the more polarised debates of comparisons of simplistic dualities, such as large- versus small-scale, bullock versus tractor tillage, general labour-intensive versus general capital-intensive mechanisation. Quite often these types of dichotomies do more to obscure and close policy debates rather than open them up.

Although mechanisation has been taking place, there have not been national and global studies of these processes and the outcomes of these changes, especially with regard to the spread of smaller-scale equipment.[4]

Spread of Smaller-scale Rural Machinery

In this section, we briefly describe the spread of smaller-scale equipment in selected Asian countries. This is more an illustrative coverage because a more comprehensive examination would require considerable resources because the national data on equipment, histories, institutions, and outcomes is either scattered or unavailable.[5] However, we hope our coverage will be adequate to focus attention on the spread of smaller-scale equipment that has taken place, especially with regard to engines of up to 20 horsepower. The common thread among most of the small machinery is the use of single-cylinder and mostly diesel engines that power 2WTs, pump sets for shallow tube wells and low-lift pumps, threshers, and road and water transport.

Table 1 gives a general time line of the historical spread of smaller equipment in some South Asian countries going back to the early 1960s.[6] From this one can see the diversity of patterns found among the countries. What the table does not show are the regional diversities within each country. For instance, within Nepal there are zones with higher levels of mechanisation and different agricultural machines compared to the country as a whole. The differences within the

[4] We are aware that there are many other studies that cover some of the issues we address here and recommend readers go to those sources: for example, Rigg (2003); Barker et al. (1985); Molle et al. (2003); Shah (2002, 2008); Erenstein (2012); and Kienzle et al. (2013). However, in this paper we focus on what we see as a neglected subject: overall issues of smaller-scale rural mechanisation. We feel these issues are all the more important today, in the global economy context.

[5] The current projects on sustainable agricultural mechanisation strategies under the Food and Agriculture Organisation of the United Nations (FAO) and the UN Centre for Sustainable Mechanisation are designed to address many of these issues.

[6] For detailed definitions of two-wheel tractors (2WTs) and their histories, origins, and spread, see the Wikipedia website http://en.wikipedia.org/wiki/Two-wheel_tractor on 2WTs, to which one of the authors (Justice) is a contributing writer.

country are due to factors, such as agrarian structure, topography, remoteness, and proximity to trade route and to other countries. Indeed, higher and lower levels of mechanisation in the central west correspond to the regional variations within neighbouring states, which indicates cross-border diffusion (Justice and Biggs, 2013).

Vietnam

Although we said at the start that we would not engage in the large- versus small-scale mechanisation debates, David Biggs (2012) described the Vietnamese history of the spread of small engines that power boats and axial flow pumps against a background of the promotion of large-scale equipment. He reported that in the early 1960s, the South Vietnamese government and a US programme were promoting larger-scale irrigation schemes, and at the same time small, 3- to 10-horsepower, US-made engines were silently spreading and used to power small boats and locally made axial flow pumps. After the mid-1980s, these small-horsepower engines (now being made in various countries in East Asia) expanded exponentially into the millions in Vietnam. In this case, the original machines were the US Clinton and Kohler petrol engines. The small, light, 5-horsepower Kohler engines became so ubiquitous that any small engine that powers a boat or a pump is called a "*may ko-le*." Significant to the early spread of the small engines was the way local innovators and rural entrepreneurs redesigned the long-tailed motorboat propellers for use with the "shrimp-tailed" axial flow pumps (Sansom, 1969).

Similar to the Nepal experience, the 2WTs initially coming from Japan, Korea, and Taiwan were first replaced by the lower-cost Chinese ones. Also, similar to the Thai and Indian experiences, the Vietnamese government established several engine and 2WT factories with the aid of other Eastern companies with concomitant import substitution. Perhaps the most important observation on Vietnam is that like Thailand and now Bangladesh, there has been a long history of a sustained, smaller-scale rural mechanisation process. As with Thailand, larger 4WTs and combine harvesters have found a market share in the county. However, the majority of tillage and other agricultural machinery are powered by smaller, single-cylinder diesel engines.

Table 1
Historical Spread of Select Smaller Equipment in Some Asian Countries

Country	Technology	1960 1970 1980 1990 2000 2010 2020
Nepal	2WTs	--Japanese---- ----Korean-Chinese in KTM--Pokhara - --Chinese All Nepal-----------
	Small Engines	--Single cylinder Indian Irrigation Diesel Pump---------Chinese Engines--------------
	Threshers	---Wheat threshers--------------------------Rice threshers--------------------------
Vietnam	2WTs	-- Import Japanese and Chinese-------Vietnamese ------
	Small Engines	------ USA Engines--------Japanese Engines ---------Chinese Engines for pumps and boats---
	Threshers	
Bangladesh	2WTs	--Japanese, Korean ---Rapid Expansion of Chinese -----l-----------------------
	Small Engines	--Japanese Diesel Pump----Rapid Expansion of Chinese for pumps, boats, etc---
	Threshers	---Wheat threshers ------------ Rice threshers -------------------
India	2WTs	-----Japanese Indian tie ups---------------------- Chinese -------------------------------
	Small Engines	-------------------------Indian Listeroids Diesel Pump-----------------Chinese for pumps, etc----------
	Threshers	---Wheat threshers ---------------- Rice threshers -------------------------------------
Sri Lanka	2WTs	-----Sri Lankan design UK made --------------- Chinese---
	Small Engines	--British-Indian Listeroids------------Chinese diesel----------------------------------
	Threshers	--------Rice threshers --
Thailand	2WTs	-----Thai developed --------------------- --
	Small Engines	--USA petrol for pumps long-tail boat ---Japanese -Thai Tie ups ---Chinese diesel and petrol---
	Threshers	----IRRI Axial flow rice threshers developed and manufactured --------------------

Source: Correspondence with W. Chancellor (July 2011) and authors' review of documents in the bibliography.

Bangladesh

Bangladesh also has a long history of smaller-scale rural mechanisation in which small engines in rural areas have powered boat and road transportation, pump sets, and 2WTs, among other usages. Before independence, the irrigation policy in Bangladesh concentrated on large-scale canal systems and deep tube wells but with at least half the country being irrigated by local small-scale equipments, such as swing buckets and *doones*.[7] Large heavy engines were used

Table 2
Small Machinery Used for Agriculture Purposes in Bangladesh

Machine	1977	1984	1989	1996	2006	2008	2009	2010	2011
2WT	200	500	5,000	100,000	300,000	343,000	366,700	400,030	420,027
Deep tubewells	4,461	15,519	22,448	24,506	28,289	31,302	32,174	32,912	-
Shallow tubewells	3,045	67,103	223,588	325,360	1,182,525	1,304,973	1,374,548	1,425,136	-
Low-lift pumps	28,361	43,651	57,200	41,816	119,135	138,630	146,792	150,613	-
Threshers (Open drum)	-	500	3,000	10,000	130,000				190,000
Threshers (Closed drum)	-	100	1,000	5,000	45,000				65,000
Maize sheller				100	850				5,000
Combine harvester						±30			100
Winnower						±500			±200
Backpack Sprayer						1,250,000			1,250,000
Reaper						±40			±50
2WT Seed Drills					451	481	620	890	1,220

Source: Table from International Development Enterprises (2012).

Note: 2WT = two-wheel tractor. Dashes indicate not available.

[7] A hollowed-out tree on a pivot used to lift water manually from canals and ditches..

for low-lift pumps in the public and private sectors where rural entrepreneurs were selling water. After independence, the irrigation policy changed radically, and the government promoted groundwater development policies, especially shallow tube wells, and the use of small horsepower, low-lift pumps for lifting water from surface sources. After the change of policy, there was much formal and informal experimentation with different sizes and types of shallow tube well and low-lift pumps and with different institutional models, such as landless labourer groups selling water and private ownership. However, it was not until the 1980s that there was a major expansion of shallow tube wells powered by Chinese diesel engines, which were cheaper and lighter in weight compared to the conventional Japanese and Indian small-horsepower diesel engines.

Some of the early introductions of 2WTs took place in the mid-1970s when a Japanese aid programme established a training centre for 2WTs near Dhaka. However, use of the Japanese 2WTs did not spread. During visits to China in the 1970s, Bangladeshi entrepreneurs began to add a few small diesel engines to their container shipments, but it was not until the restrictions on the import of Chinese equipment (because they were considered of inferior quality) were lifted in the late 1980s that the rapid spread of Chinese-made engines (for irrigation) and 2WTs took place. Table 2 demonstrates how by 2011 smaller-scale equipment spread in Bangladesh to 420,000 2WTs[8] and 1.4 million shallow tube wells.

Thailand

The spread of smaller engines in Thailand also has a long history. Grandstaff *et al.* (2008, 336) describe how the use of 2WTs in the rainfed region of the Northeast of Thailand rose rapidly after the beginning of the 1980s. In 1983 there were 40,000 2WTs, and the number rose to 1,250,000 in 2003. Agricultural- holding households owning 2WTs rose from 2 percent to 47 percent in 2003. By 2003, 89 percent of households were using 2WTs, and hiring practices were widespread. In this case, the 2WTs were part of the intensification of a rainfed rural economy. In other parts of Thailand, the pattern of small-scale mechanisation was different. There are 1.8 million 2WTs, and nearly 2 million to 3 million small- horsepower pump sets (Thepent, 2011; Faures and Mukherji, 2009). The history of Thailand's small-scale pump set

[8] As Biggs, Justice, and Lewis (2011) discuss, reliable statistics in developing countries on agricultural machinery are very difficult to obtain. During the Bangladesh workshop where this paper was first given the "updated" statistics provided by many people on the total number of 2WTs in Bangladesh was 600,000 to 700,000 units.

irrigation was different from that of Bangladesh as the use of surface water from canals, small rivers, and farm ponds has been much greater. But the importance of small pump sets to pump from these canals is just as important. The types of pumps also differed. In the early 1960s, Thailand developed locally produced axial flow pumps, likely an innovation borrowed from the Vietnam shrimp- tailed/propeller pumps. Although axial flow pumps are one and a half to two times more expensive than conventional centrifugal pumps, they have half or less the energy consumption of centrifugal pumps at lifts below 3 meters. However, Facon (2002) notes that in the mid-2000s, there has been an explosion of shallow tube well development in certain parts of the Chao Phraya delta, which perhaps indicates that the availability of surface water may have reached its limits.

The history of the spread of smaller equipment in Thailand has been characterised by the strong support and promotion by the government of private agro-machinery industrial development. Since the early 1960s, there have been substantial programmess for the promotion of manufacturing of both the earlier small and the more recently larger agricultural machinery. Chinsuwan and Cochran (1985) describe a government-led programme for the development and manufacturing of axial flow pumps. William Chancellor (personal communication, August 2011) reported that the "Thai"-type 2WT was initially developed in the late 1950s by M. R. Debriddhi, head of the engineering division of the Thai Rice Department of the Thai Ministry of Agriculture and Cooperatives.[9] Debriddhi spent many years cooperating with several manufacturers to promote the spread of this technology. Referring to the spread of axial flow rice threshers in Thailand in the 1980s and 1990s, Chancellor also related that the International Rice Research Institute, in the 1970s and early 1980s, "through its newly created Industrial Extension Programme had extended axial-flow threshers to Thailand" and that the "Government of Thailand had responded with a relatively large programme for their promotion with many local manufacturers." Later, Thepent (2009) describes a series of these government projects beginning in 1983 with the development of locally made track-type combine harvesters that led to the first commercially manufactured combines in 1989. Thepent attributes the success of the combines to building on the earlier success in the development of the axial flow rice threshers that were incorporated in the combine harvester's designs.

[9] Also see Chancellor (1998).

Today, Thailand is a mixed system where Thai-made 2WTs still do most of the land preparation for rice (although in the last few years 4WTs have begun to spread but mostly in the upland maize areas north of Bangkok) but where larger-horsepower Thai-made threshers and combine harvesters greatly aid in the harvest of rice. Thepent relates that Thai farm holdings continue to fragment and get smaller but that if the high support prices for rice from the Thai Government do not continue this could slow or even reverse the land fragmentation (Thepent personal communication, February 2014).

Sri Lanka

Sri Lanka is, especially interesting as regards 2WTs because one of the early designs of a South Asian 2WT was by Sri Lankan Ray Wijewardene in 1955. This model ended up being manufactured in the United Kingdom by Landmaster with exports back to Sri Lanka. By 1975, there were 11,000 2WTs in Sri Lanka. The UK 2WTs gave way to Chinese imports in the 1980s. By 2007, there were 125,000 2WTs in Sri Lanka. As with Bangladesh, these 2WTs are generally used for multiple purposes, such as transport, tillage, and harvesting. Rural entrepreneurs who own them, but who do not necessarily operate them, hire out services (Biggs *et al.*, 1993). It is estimated that more than 80 percent of all tillage operations are mechanised, and much of this is done by 2WTs. In addition it is estimated that by 2000 there were more than 100,000 smaller-scale engines used for shallow tubewell pumps (Barker and Molle, 2004; 2005; Kikuchi *et al.,* 2003).

India

Since the 1980s the Indian Government has made significant investment in smaller-scale equipment through agricultural research and extension policies. The All India Coordinated Research Project on Farm Implements and Machinery and the various departments of agricultural engineering in the many agricultural universities in India have long-term projects for the research, development, and promotion of small-scale agricultural machinery. Other central and state-funded programmes provided large and long-term subsidies for 2WTs and small machinery. However, if one looks at access to powered machinery for tillage, harvest, and threshing, India looks very different from its neighbours. In Bangladesh and Sri Lanka, more than 80 percent of tillage operations are mechanised- mainly by 2WTs- whereas in India mechanised tillage and crop establishment makes up 45 percent (Kulkarni, 2005; Pandey, 2009; GOI, 2013).

The slow spread of smaller-scale equipment in India is a paradox. Table 3 shows the percentage of the total 2WTs in the Asian region, by country. The unexpected figure is that the whole of India has only about 300,000 2WTs or 1.5 percent of the total, which is less than the 500,000 2WTs or 2.5 percent for Bangladesh. Ten years ago, there was an even wider disparity, with 350,000 in Bangladesh and approximately 120,000 in India. From the 1970s, the government supported Japanese-Indian 2WT joint ventures of which only two survive. From the 1980s to 2000, VST Bangalore from Mitsubishi and Kamco Kerala from Kubota had nearly the whole market to themselves, selling higher- quality but also much higher- priced 2WTs. Recent industry reports state that 2WTs sales started picking up in 2005, and by 2010 the industry had a growth rate around 20 percent per year. Recent sales are reported at upwards of 45,000 to 55,000 per year. In contrast, in 2001, sales were less than 20,000 (Kulkarni, 2005). In the 1990s, Chinese 2WTs began making inroads, and today, according to market reports for the past five years, they may have gained 35 percent or more of the market share.[10,11]

As indicated by countries, such as Bangladesh, Thailand, and Sri Lanka, the recent rapid spread of smaller-scale machinery has increased the productivity of agricultural and other rural resources. The paradox then is, How is it that even with large government support, investments in the research and development (R&D) as well as in the manufacturing of 2WTs, and the sizeable potential for small-scale equipment to increase the intensity of use of agricultural and other resources, the spread of smaller-scale equipment has been so low in India?

A complete answer to this complex question is beyond the scope of this paper. However, we suggest that part of the explanation is that agricultural mechanisation in India has been largely dominated by the corporate manufacturing sector. In particular, the indigenous 4WT industry has seen the entry in the past decade of multinationals, such as AGCO/New Holland, John Deere, and Deutz Farh. India became the largest manufacturer of 4WTs in the world in the late 1990s, yet it was accompanied by the neglect of the machinery requirements of cultivators and other rural entrepreneurs in rural areas,

[10] Kulkarni, in *Business Standard*, and Sushil Finance, also in *Business Standard*, gave a 15-25 percent annual growth rate starting from 2005. Until then the market had been stagment, with few or even decreasing sales. It is not clear what exactly changed to drive this growth.

[11] Reference the World Bank's (2011) *The Ganges Strategic Basin Assessment*, which states that excluding Bangladesh, much of the eastern Gangetic plains shallow aquifers are underutilised.

Table 3

Estimates of the Two-wheel Tractor in Some Asian Countries, 2012

Country	**Number**	**Percentages**
Pakistan	1,000	<1
Bhutan	3,000	<1
Afghanistan	8,000	<1
Nepal	20,000	<1
Sri Lanka	150,000	<1
India	300,000	1.5
Bangladesh	500,000	2.5
Thailand	1,800,000	9.0
China	17,000,000	85.9
Total	19,782,000	100%

Source: Authors' estimates based on IFPRI (2014), J. Kienzle, J. E. Ashburner, and B. G. Sims, eds. (2013), Wang (2013).

especially in the poverty areas of the eastern and central regions of India. Consequently, for the sake of this review of the long-term sustained spread of smaller-scale equipment in the intensification of agriculture and the rural economy, surprisingly India has limited knowledge to share, although that may now be changing.[12]

Nepal

The first 2WTs came to Nepal via Japan in the 1970s. Korean and Chinese 2WTs entered in the 1980s, but as sales were limited to Kathmandu and Pokhara Valleys, sales were slowed and stopped in the 1990s (Biggs *et al.,* 2002). In 2000, sales began anew but only for Chinese 2WTs. Today, it is estimated that there are more than 20,000 2WTs in Nepal, with sales of 1,500 to 2,000 per year.

Japanese and Indian small-horsepower diesel pump sets for irrigation started in the 1970s. However, even with subsidies their sales were always disappointing.

[12] There is considerable evidence that policy practice is now changing in India, for example, the dramatic rise in the imports of Chinese equipment. The National Bank for Agriculture and Rural Development has undertaken research and is now giving special attention to loans for small-scale equipment.

Their sales dropped after the subsidy was withdrawn in 2000. In 2004, less expensive and lighter-weight Chinese pump sets entered the market, and sales picked up to 5,000 or more per year. Figure 2.1 illustrates how much the choice of technology has opened up for cultivators and rural entrepreneurs since the 1980s and 1990s when there was only the choice between a Fieldmarshall or Kirloskar, nearly identical, very heavy, and very expensive irrigation Lister-type diesel engine pump sets. Figure 1 shows three pictures of a single store in Narayanghat, Chitwan, where there is a wide array of choices from Kirloskar to many sizes of Chinese diesel, petrol, and petrol/kerosene engines as well as a similar wide array of Chinese and Indian electric, above-ground, and submersible borehole pumps.

Figure 1
Wide Range of Engines Available in Nepalese Market

Source: Authors (2013).

Note: These three photographs of a single hardware shop in Narayanghat, Nepal illustrate the wide variety of electric submersible and electric, diesel, petrol, and petrol/kerosene above-ground pumps available on the market in Nepal.

A paradox also exists in Nepal. After the introduction of Japanese 2WTs in the 1970s in the Kathmandu and Pokhara Valleys, 2WTs made significant contributions to increased agricultural productivity in those valleys. However, the paradox is that there was little governmental and donor support for this type of smaller-scale mechanisation until the late 1990s. At that point, new demonstrations and research on 2WTs were initiated on the Terai and initiatives taken to encourage the import and sale of 2WTs. There is now an estimated population of 20,000 2WTs in Nepal.

Another paradox in Nepal was that discussions of rural mechanisation were left out of early five-year development plans, and the national Agricultural Perspective Plan (APP) in 1996 excluded a discussion of agricultural and rural mechanisation. Although the irrigation sector received some recognition in the APP, the critical inputs of small-scale groundwater development and local canal water systems were assumed to be addressed through the technical abilities of other ministries and institutional coordination between ministries. However, little research on the effective, careful use of water at the farmer level took place, and little communication took place. In the early 2000s, the minister of agriculture and the Asian Development Bank (ADB) tried to address these issues and modify the APP, but little changed. Hence, it can be seen that the APP itself was one of the reasons why the intensification of agriculture and the development of the rural economy through smaller-scale rural mechanisation was not addressed earlier.

In addition, the main banks in Nepal are still *traditional* and slow to create financial products for poorer people who do not have land or other collateral that would allow them to invest in smaller-scale equipment.

A relatively new entrant onto the mechanisation scene of Nepal is the spread of smaller- horsepower 2WTs or mini-tiller tractors shown in Figure 2.[13] These were initially brought in around 2005 by a few private-sector agricultural input traders who saw them on trips to China. The mini-tillers initially spread in peri-urban areas for vegetable production. There has been some government-sector support, [14] and they are now spreading in rural and mountainous areas where the larger 12 to 15-horsepower 2WTs are too large for the small terraces and difficult access conditions. There are ten or more mini-tiller importers, and they sold an estimated 500 units in 2012. The government of Nepal and donor-funded projects are attempting to backstop their spread and attempting to find additional implements and uses similar to the larger-horsepower 2WTs.

[13] These are four- to eight-horsepower rotary tillers that usually come with interchangeable rotovator blades and rubber tires.

[14] Support was initially in the form of training and demonstrations from the Department of Agriculture's engineering directorate. Later, various District Agriculture Development Offices and District Development Committees on their own initatives began buying them for farmer groups. This indicates a new vibrancy on the part of some district-level officers for decentralised public-sector agricultural development.

Figure 2

Petrol-Engine-Powered Mini-tiller Puddling Soil for Rice on Terraced Hills behind Bhaktapur

Source: S. K. Sharma (2014).

Until recently the Nepal importers had offered only mini-tillers with rotovators for ploughing. However, government and donor projects that have taken interest in these mini-tillers are now working with the importers to develop and offer other mini implements, such as seed drills, irrigation pumps, open drum threshers, milling machines, and trailers that would make these mini-tiller power sources even more useful and beneficial to small-hill farmers.

Until recently the Nepal importers had offered only mini-tillers with rotovators for ploughing. However, government and donor projects that have taken interest in these mini-tillers are now working with the importers to develop and offer other mini implements, such as seed drills, irrigation pumps, open drum threshers, milling machines, and trailers that would make these mini-tiller power sources even more useful and beneficial to small-hill farmers.

Mini-tillers are part of the programme of a women's micro finance group, Mahila Shayatra Microfinance Bittiya Sastha Ltd. The machines fit within the small-loan credit limits. Also, their small size allows women to operate them and opens up diversification of livelihoods for women farmers (Sumitra Manadhar Gurung, personal communication, 2013). While on a visit to this group in Makwanpur District, the authors noted that one of the first users of the mini-tiller was an older couple (husband age 68 and wife age 58) whose children were working in Kathmandu. They were both operating the mini-tiller to plow their 0.66 hectares, suggesting that this small equipment might also address the problems of aging farm households.

In a new Agricultural Development Strategy document by ADB, two issues are highlighted:

(1) the importance of agriculture and rural mechanisation and (2) renewed attention's being paid to the importance of irrigation, especially shallow tube wells in the Terai (see Tomecko and Poshan, 2012; ADB, 2011; Cook *et al.,* 2012). However, because of the great range of farming conditions in Nepal, diverse irrigation technologies, including small-scale pumps and tanks, drip irrigation systems will be more effective ways to improve agricultural intensification in many situations, for example, areas of high-value crops with plastic tunnels and houses, where mini-tillers and other technologies are already spreading.

From a rural engineering perspective, micro hydro and other forms of engineering-based green energy sources are increasingly important in Nepal. In the hills and mountains water mills have for centuries been used for grinding grain, pressing oil, and so forth. Since the 1960 there have been many programmes to improve water mills and small-scale hydro, and it is estimated there are now about 8,000 improved water mills, and more than 2,500 micro hydro-electric installations with installed capacity of 37 MW, from the smallest pico hydro of a few kilowatts to the mini hydro systems of up to 1 megawatt (AEPC, 2011). The recent arrival in local hardware stores of Kathmandu of low-cost imports of micro and small scale hydro-electric turbines from China will probably lead to faster spread of smaller scale hydro- electric units.

Cambodia

Cambodia's national mechanisation process stands out for many reasons. It is mostly a rural agrarian country in which more than 70 percent of the population earns a living from an agricultural sub-sector where the average holding is less than two hectares. Cambodia is also sparsely populated compared to other South and East Asian economies. However, it is estimated that there are nearly 3 million hectares of arable land uncultivated, of which nearly 2 million hectares have been leased out on long-term leases, in what some people term "land grabs," to various multinational corporations (Fighting land-grabs 2013). Many rural people are beginning to prosper due to the agricultural intensification through the spread of small-scale irrigation pump sets, 2WTs, 4WTs, and threshers that allow for the addition of dry season winter rice and other crops. Alongside this growing commercialised smallholder rural economy the large- scale corporate agricultural subsector has brought a parallel market for large tractors, planters, and other machinery. Although the government is attempting to provide support to both sectors, the demands by the larger corporate subsector are distracting from or diluting limited government resources from the needs of the smaller-scale rural economy.

Dynamic Alliance Consulting (2011) reports that agricultural mechanisation has increased sixfold in Cambodia. Table 4 shows concomitant growth of the agricultural machinery sector. Once a net rice importing nation, Cambodia is now unofficially exporting 1 million to 2 million metric tonnes of unmilled rice to Vietnam and Thailand. This may soon change as the large investment in the auto rice milling industry in the past three years will allow for value addition and support a growing trend to market-milled Cambodian rice by Cambodians (WSJ, 2013).

Table 4
Growth of Farm Machinery in Cambodia

Item	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tractor	3,072	3,293	3,310	3,857	4,166	4,247	4,475	4,461	5,495	5,893
Tiller	8,789	9,782	13,693	20,279	26,504	29,706	34,639	38,912	54,163	60,941
Harvester	-	-	-	-	-	395	395	430	836	859
Thresher	3,780	4,199	4,967	6,220	7,338	7,795	8,036	8,237	13,798	14,262
Engine pump	64,406	87,622	99,875	106,569	120,968	127,610	131,702	136,061	164,482	167,152

Source: Table taken from Dynamic Alliance Consulting (2011) report illustrating the growth of farm machinery in Cambodia.

Note: Tiller = Thai two-wheel tractor. Dashes indicate that data is not available.

Afghanistan

Afghanistan has perhaps one of the shortest histories of smaller engines and smaller equipment.[15]Agricultural mechanisation in Afghanistan was influenced by the former Soviet regime's collective ideals of large-scale machinery. Similarly, Pakistani influences have been mostly of the Punjab large-scale machinery type. Indeed, with an impending United States Agency for International Development (USAID)–sponsored 2WT dissemination project looming in 2009, project staff were inundated with complaints from the Department of Agriculture that were premised by, "We are a 4WT nation and these 2WTs will never sell." However, shortly thereafter, more than 4,000 2WTs with plows, reapers/harvesters, seed drills, and trailers were sold, albeit with a generous USAID-supplied 60 percent copay[16] within a nine-month period.

Interesting to note, another USAID Afghanistan Vouchers for Increased Production in Agriculture South project intended to distribute 15,000 small-horsepower Chinese diesel pump sets to farmers along the Helmond River. However, the provincial governor feared a water war would erupt, with river tail enders getting even less water, and stopped the project. Notwithstanding this, during the past ten years large numbers of small-horsepower Chinese single-cylinder diesel engines have been imported and sold for generating electricity for irrigation pumping and threshing. A rough estimate would put the number of 2WTs in 2013 in Afghanistan at 9,000 and small pump sets at 30,000.

Bhutan

It is estimated that there are more than 3,000 2WT in Bhutan, which were introduced under a long- standing Japanese aid programme. Bhutan is interesting in that from early 2004 there has been a funded power tiller "track" programme to build narrow, lower-cost tracks in rural areas to increase accessibility for 2WTs. In a mountainous country, where the cost for investment in and maintenance of wider, hard-top roads is high, narrower and less engineered green roads are seen as a viable transport and rural development initiative (Tobgay and McCullough, 2008).

[15] This section is based on the personal experiences of one of the authors working in Afghanistan in four mechanisation projects from 2005 to 2011.

[16] Today, "farmer copay" and "vouchers" have become substitute terms for "subsidy" among many unilateral and multilateral donors.

Six Observations

The brief and select histories of the spread of smaller-scale equipment in the preceding section illustrate the diversity of rural mechanisation processes that have taken place. In this section, we draw out some general observations to provide a background for the discussion of the themes.

Observation 1: Long Histories and Mixed Heritage of Smaller-scale Engines

In South and Southeast Asia, there are diverse patterns of rural, smaller-scale mechanisation.[17] Many of these have long histories going back to the 1960s, and some other countries and regions, such as Afghanistan, Myanmar, and Bihar, have only recently seen the more rapid spread of smaller-scale diesel engines. The history of imports and local manufacture is also varied, as is the sequencing of operations that mechanised before others. In Bangladesh, clearly small pumps for irrigation came before 2WTs. In Northeast Thailand it was the spread of 2WTs in rainfed agriculture that led to increased rural development. In Bangladesh, Vietnam, and parts of Thailand, the use of smaller-scale engines with boats and shrimp-tailed propeller pumps formed the major part of the history. In many of the countries, the use of smaller-scale engines for transport (by water and on land) as well as agricultural purposes was a central feature in understanding their spread.

As we mentioned at the start of this paper, we are not looking at the spread of larger-scale equipment, such as 4WTs, large combines, harvesters, large-scale deep tube wells, and large-scale rice- milling equipment or at the engineering of large-scale canal systems. This is not because a historical analysis of rural mechanisation would need an analysis of the overall relationships between the different scales of technology. Rather, it is because this paper is concerned with the histories and lessons coming from smaller-scale rural mechanisation that are often neglected in some global and national rural mechanisation policy debates.

In summary, the lessons from these histories are the following:

- Long histories of substantial smaller-scale rural mechanisation, for example, Vietnam, Bangladesh, Sri Lanka, Thailand, and parts of India and more recently spreading in Bihar, Nepal, Afghanistan, and Bhutan.[18]

[17] Recently, Diao et al. (2014) have taken illustrative representations of different patterns of agricultural mechanisation in China, Bangladesh, and India to illustrate the importance of considering alternative institutional models in policy analysis in Ghana.

[18] In this paper we do not look at China, where, as illustrated in Table 2.2 it can be seen that the number of 2 wheel tractors is huge.

- Diverse patterns of rural mechanisation.
- Increasing diversity of models and sizes of machinery and their sources of fuel (diesel, electric, petrol, kerosene, compressed natural gas [CNG], and now solar sources).
- Different sequences in the mechanisation of rural and agricultural operations.
- The importance of the use of tractors and other engines for transport.

Observation 2: Multiple Uses of Smaller Engines and Multiple Markets for Engine Services

The second observation concerns the multiple uses and diversity of market institutions for the services of smaller-scale engines. Not only have small-scale engines been used for many purposes, such as powering boats, pumping water, milling, hulling, threshing, processing agricultural products, and powering 2WTs, but the same engine has been put to multiple uses. For example, a 2WT of the Kathmandu and Pokhara Valleys is generally used for transport, tillage, and other rural operations as well as for the transport of construction and other goods in the local coterminous urban areas. In Sri Lanka, 2WTs are used a great deal as taxis or buses as well as for agricultural purposes. In Nepal, pump set engines are widely used to power threshers.[19]

Alongside the spread of smaller-scale engines and other smaller-scale equipment has been the spread of a great range of market institutions for the buying and selling of services. In Bangladesh, the markets in water and 2WT services have long been documented by Mandal (2000) for 2WTs in Sri Lanka (Biggs et al. 1993) and Thailand (Grandstaff *et al.*, 2008). In the Kosi region of Bihar, the spread of bamboo tube wells was facilitated by rural entrepreneurs who sold pumping services from a heavy Indian diesel pump set mounted on bullock carts (Appu, 1974). As a result of the remunerative benefits of 2WTs, custom service markets in Nepal, some have had a long life. Indeed, some of the original Japanese and Korean 2WTs are still operating and providing their owners income after 30 years. Notwithstanding this, the general payback

[19] Interesting to note, in Nepal the engines of traditional larger-scale combine harvesters often remain unused outside of the harvest season. Apparently, investment decisions are such that for those who own such large engines, it is unnecessary to utilise the engine more fully as a power source for other operations. However, even this practice is now changing with four-wheel tractors (4WTs) being used on combined harvester equipment to provide the power source.

period on total investment for a Chinese 2WT in Nepal and Bangladesh has, and continues to be very good, generally less than 2 years.

Observation 3: 'Good Enough' Profitable Equipment with Smaller Engines is Owned by Rural Entrepreneurs

The third observation is that it was good enough equipment, owned by rural entrepreneurs, that has spread. In the overall picture, the light, single-cylinder diesel Chinese engine played a major role. Before the imports of Chinese equipment to Nepal, the Japanese and Korean 2WTs proved to be robust over the long- term with some still in operation in the Kathmandu Valley. We use the term "good enough"[20] to highlight the issue of who sets the standards for the manufacture /import of equipment, its promotion, or both. The Bangladesh case illustrates how technical standards set by the relevant government authority prevented the importation of 2WTs from China. When the government lifted the restriction, importation of equipment expanded rapidly. However, the change came after five to ten years of government, donors, and non-governmental organisations' (NGOs) formal and informal experimentation with different types of equipment and institutions. The paradox of India's low numbers of 2WTs is brought out again in this regard. India has also set up technology vetting centres in Madhya Pradesh, Haryana, Andhra Pradesh, and Assam through which the manufacturers and importers must pass to participate in the large government agro-machinery subsidy programme. There is also evidence that this long-term subsidy programme has driven up the prices for farmers who cannot participate in the subsidy scheme due to limited size of the scheme. As we saw in Table 2.3, of the total number of 2WTs in India, Bangladesh, and Nepal, the majority were in Bangladesh (2.5 percent), with only 1.5 percent in the whole of India. This picture is now changing as it is estimated that about 55,000 2WTs per year are being sold in India and nearly 35 percent of this total is imported from China by Indian companies.

The second point to note is that the smaller-scale equipment is owned by rural entrepreneurs and is highly profitable. This is illustrated by 2WTs. In Bangladesh, Nepal, Sri Lanka, and Thailand, they are owned by people who may have some land, but generally their services are hired out to others for multiple purposes. Transportation is the most common nonfarm use.

[20] We first came across this term in Qiuqiong, Rozelle, and Hu (2007), who use the term in describing the smaller-horsepower Chinese electric motor industry used in irrigation and other rural and agricultural mechanisation processes

However, applying the "non-farm" label to transport and other activities is problematic. In the places where smaller-scale engines have spread, the engines are used as much for nonfarm use as for farm use, and it is this flexibility that has made them attractive to rural entrepreneurs as an investment.[21] There are numerous studies of the use and markets of services of smaller-scale equipment and their profitability.[22] In a recent study in Bangladesh[23] it was found that the time to recover full investment costs in shallow tube wells, 2WTs, and power threshers was 2.5, 1.8, and 1.5 years, respectively. The same survey shows that funds for investments in shallow tube wells, power tillers, and power thresher come mainly from investors' own savings, family, and so forth rather than from bank loans. In recent years, the source of loans, especially from friends and relatives, has grown. Some of this own savings may well be coming from remittances of labourers from rural areas working in the Middle East and other countries. The same recent Bangladesh study showed that more than 90 percent of farmers who own 2WTs hire them out, and 25 percent or more of farmer/owners hire out their shallow tube wells and power threshers. In some policy and technology discussions, the idea is introduced that smaller-scale equipment is for multiple use on self-contained small farms that have little contact with outside local markets. The Asian data clearly show that this representation of a small farm agrarian/rural economy is incorrect.

In many situations the equipment is operated by paid labourers who are also responsible for renting out the machinery on a daily or monthly basis. These 2WT operators generally do not have access to savings and loans by which they can buy and operate their own machinery.[24] In Nepal, becoming a 2WT operator is seen by some labourers as a routeto a better-paid, more lucrative and respected bus or truck driver jobs. [25]

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[21] This applies even more so to the larger four-wheel "agricultural" tractor, which, for example, on the Indian and Nepal Terai (Gangetic plains), in the mid and high hills of Nepal, and in parts of Bangladesh is primarily used for transport purposes of diverse goods.

[22] See, for example, Biggs (2012), Grandstaff et al. (2008) and Biggs et al. (1993), Appu, (1974), Alam et al. (2004)

[23] See Hossain et al. (2013).

[24] Obtaining credit from the formal banking system by poorer rural people is notoriously difficult in most countries, even in Bangladesh with its long history of micro finance. However, a new credit program with refinance by the Central Bank of Bangladesh was started in 2009. It was based on the rationale: "Due to the ineffectiveness of conventional micro-credit and formal banking systems to reach agricultural credit to marginal and small farmers who dominate the agrarian structure in Bangladesh" (BRAC 2012). In Nepal in 2004, the Poverty Alleviation Fund was prepared to refinance loans for 2WT and other smaller-scale equipment to poorer rural households. However, Nepal banks were not prepared to move into this work. A new bank, Mahila Sahayatra Micro Finance, started in 2012 and now has provisions to make loans for equipment to poorer rural entrepreneurs without land or other assets.

[25] For details of the ways these 2WTs and service markets have been operating in Bangladesh for many years see Alam et al. (2004) and International Development Enterprises (2012).

Observation 4: Energy Policy is a Central Component—Availability and Prices of Electricity and Fossil Fuels

Table 5 illustrates that different countries have different sources of energy and energy policies. For example, in India 25 percent of the horsepower in agriculture comes from electric engines, whereas in Bangladesh and Nepal it is only 6 percent and 11 percent, respectively. Two-wheel tractors have been powered by diesel. The power source for irrigation pump sets has been more diverse, including electricity, diesel, petrol, and kerosene. In Bangladesh, shallow tube wells and low-lift pumps have been powered mainly by diesel fuel. [26]As an overall observation, it would seem that smaller-scale shallow tube wells have spread more rapidly where diesel/petrol pump sets have been available and promoted. In some situations, the unreliability of electricity is a well-known problem, which can be costly for cultivators. The lack of the availability and promotion of lighter-weight and inexpensive Chinese diesel-powered pump sets and 2WTs in Eastern India could be some of the explanation for the slower growth of the agricultural sector and other parts of the rural economy. That now is changing with the increased spread of smaller-scale equipment, some of which in earlier days used to come over the borders from Bangladesh and Nepal. Interesting to note, a Bangladesh policy to promote the use of CNG from its own supplies for use in domestic vehicles has not led to the spread of CNG for powering these engines in rural and agricultural areas. This may be because CNG is less available in the rural areas and that the appliances needed to convert these rural engines to CNG have not been developed. However, as a result of the policy, imported diesel is freed up for use in rural areas.

Nepal's underdeveloped hydroelectricity potential has also directly affected choice of technique as regards electric or diesel engines for pump sets. This might be beginning to change now for a number of reasons: (1) more decentralised electricity user groups whereby electricity is sold in bulk to user groups and (2) the spread of smaller-scale hydroelectricity plants with increased attention given to the use of electricity for economically productive purposes, such as local irrigation, processing, and other rural economic activities.

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[26] The diversity of energy policies within countries also affects the supply and use of power. For example, different states of India have different policies for the supply and pricing of electricity (Mukherji, Shah, and Verma,

Table 5

Composition of Mechanical Horsepower by Engine Size in Bangladesh, India and Nepal, 2012

Energy Source	**Number of Units**	**Total Horse Power**	**Total Horse Power (%)**	**Number of Units**	**Total Horse Power**	**Total Horse Power (%)**	**Number of Units**	**Total Horse Power**	**Total Horse Power (%)**
Two-wheel tractors[a]	500,000	7,500,000	53	300,000	4,500,000	2	16,000	240,000	13
Four-wheel tractors[b]	35,000	460,000	3	3,500,000	122,500,000	56	30,000	900,000	51
Irrigation shallow tubewell pump-diesel[c]	1,200,000	6,000,000	42	9,000,000	45,000,000	20	120,000	600,000	34
Irrigation pump sets-electric[d]	100,000	200,000	1	12,000,000	48,000,000	22	10,000	40,000	2
Total		14,160,000	100		220,000,000	100		1,780,000	100

Source: Authors estimates

Note: Estimates of the numbers of power sources (and their horsepower ratings) are used primarily in agricultural and processing uses, including groundwater irrigation pumps. Estimates do not, for example, include the many engines used in Bangladesh to power riverboats, rice mills, processing, and so forth, although these are a major part of the Bangladesh agriculture and rural economy. a Average of 14 horsepower per two-wheel tractor. b Average of 30 horsepower per four-wheel tractor. [c] Diesel/petrol irrigation pump sets are average 5 horsepower; 5–10 percent of the pump sets are petrol/kerosene. [d] Average electric tube well is 4 horsepower.

It is also seen that India has the highest usage of electricity at the farm level. The large and mostly state-funded electricity subsidies have led to high levels of usage by farmers, especially for irrigation. This also has led to the well-known unsustainable mining of the aquifers in the drier, and more affluent, northwest (Gupta *et al*., 2003)

Observation 5 : The Importance of Informal R&D

In many of these histories, informal R&D has been important, if not central, to understanding the spread of the smaller-scale technology. In the case of Vietnam, the use of the small engine came about because a local engineer saw the potential of changing the use of the equipment for power boats and axial flow pumps (Biggs, 2012; Sansom, 1969). Similarly, in Bangladesh local engineers and artisans modified and adapted the Chinese engine for different purposes from those for which they were initially introduced. The spread of bamboo tube wells in the Kosi region of Bihar was a classic and well-documented example of where a government tube well package was unpacked. The diesel pump set was then mounted on a bullock cart to sell pumping services to farmers who had cheap bamboo wells sunk on their own fragmented plots. Innovation also took place on the institutional level in the creation of local markets in services. An example of an institutional innovator was a local administrator who went against the grain and created a local government program to promote the spread of irrigation through this new technology (Appu 1974). More recently, the efficiency of shallow tube wells has been improved by the spread of inexpensive plastic lay-flat pipes[27]

[27] Lay-flat pipes are made of cheap, locally produced plastic flexible hose pipe that enables water to be pumped to specific fields where and when wanted; in doing so, the pipes address a whole range of ownership, timeliness, small plot, and fragmented plot problems. Lay-flat pipes reduce conveyance losses (> 20 percent water savings), reduce labour as there is no need for tertiary ditches, allow movement of water over or under previously impassable obstacles, reduce conflicts as traditionally moving of water near or through neighbors' fields was a potential source of conflict, and even increase yields via better "in-field" water management.

in Nepal and elsewhere (de Bont 2014). These flexible delivery hoses originated in the black plastic pipe extrusion industries in South Asia (Figure 3).

Figure 3

Simple, Inexpensive, Locally Produced Via Plastic Extrusion, Lay-flat Flexible Hose Pipe

Source: Scott Justice (2004).

The lay-flat pipes rapidly became so common that in some areas local people do not even see them as being new or unusual. More recently, Pearce (2012) reported that in India ice pop wrappers are now being used for drip irrigation at a cost far below the more conventional designs coming from the market or more formal R&D programmes. In these cases, informal R&D has proved itself an important source of innovation for the management of irrigation water.

In Bangladesh, the 2WT reduced or zero-till drill that was promoted by the International Maize and Wheat Improvement Centre in the late 1990s and early 2000s for wheat and other grains spread quickly, not for reduced till wheat but as a high-speed rotovator tiller used for onion and other high-value crops.

According to International Development Enterprises (2012), by 2012 their numbers had grown to more than 2,000 pieces, and importers were actively marketing them as high-speed rototillers. In all these situations, local innovators have transferred materials and equipment from one part/sector of the economy to another to create new techniques/institutions.

Observation 6 : The Political Economy of Agrarian and Rural Change in a Broader Context

The final observation concerns broader political economy, trade, and development issues. In this brief illustrative review, we have not looked at gender, caste, income distribution dimensions of the spread of smaller-scale equipment, as that has been beyond the scope of this paper. However, we suspect that the spread of smaller equipment is more equitable than that of larger equipment. Such an analysis would require a different review of evidence and analysis. We also have not looked at the health and safety dimensions of the spread of this type of equipment. Accidents due to machinery are notoriously high in agriculture and rural industries and the rural transport sectors in most countries, especially among labourers and poorer farmers and rural entrepreneurs. This is another issue that requires further research. Even when regulations and standards are present, effective health and safety practices do not appear to be a major concern of practitioners involved in rural mechanisation R&D, promotion, and effective private- sector or public-sector monitoring and enforcement.

The most important political economy observation is that the spread of smaller-scale equipment in rural areas of some South Asian countries cannot be understood without looking at the structure of the agricultural and the broader rural and national economy. Factors that need to be considered are (1) the relationship of the rural economy to the rest of the economy, (2) trade regimes, (3) the extent of migration, and (4) whether the country is in a conflict or a post conflict situation. We conclude that much of the literature concerning agricultural and rural mechanisation, agrarian and rural change, and choice of technique has often overlooked the significance of these broader issues and as a result has presented only partial and sometimes unhelpful conclusions. The continuation of such partial analysis is particularly problematic now when dimensions of rural mechanisation are central to policy debates on food production and security, ownership and management of land, rural equipment, land grab debates, and rural employment and migration. Any discussions concerning the implications of different patterns of land ownership will not move the debate forward unless they contextualise rural mechanisation choices within national and global settings.

Expanding the Policy Debates

Some readers may be frustrated that we have given minimal detail in our observations about the spread of different patterns of smaller-scale rural mechanisation in some other South Asian countries during the past 60 years.[28] We trust that more detailed analysis will provide support and nuance to our general observations. We now move to themes that need to be addressed if policy debates are to be further opened up. We say "further opened up" because many Asian countries in recent years have seen substantial growth in their rural and agricultural economies. Even the most enthusiastic proponents of large-scale commercial agriculture will be hard pressed not to see the connection between productivity increases in smaller-scale agriculture and the spread of smaller equipment.[29] We feel the policy debates are being opened up now, not because academics and centres of global policy analysis on agriculture and food have led the way but rather because global events have demanded attention be given to these issues. These include events, such as food riots, land grabs, and the associated promotion of large-scale mechanisation equipment, scarcity of water and energy, emerging remittance economies, and global trade in intermediate goods.[30] These emerging issues are slowly bringing rural mechanisation issues to the fore of global economic policy debates. However, before discussing ways forward in policy we need to look at some themes that have characterised this area of policy discussion in the past and which, if not adequately addressed now, will, in our view, continue to bias policy discourses in the future.

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[28] That said, the former United Nations' Asian and Pacific Centre for Agricultural Engineering and Machinery (UNAPCAEM)'s website, now called Centre for Sustainable Agricultural Mechanisation, has a small treasure trove of presentations and reports waiting to be mined on various aspects of agricultural mechanisation by senior agricultural engineers from many member countries dating from the past ten years. The documents can be found at http://un-csam.org/cp_index.htm.

[29] In an earlier article, we argued that these bigger debates on rural mechanisation needed to be opened up, having been closed down since the 1970s (Biggs, Justice, and Lewis 2011).

[30] Examples include 2WTs and their attachments, diesel pump sets, electric motors of all sizes, and a whole range of renewable energy technologies. Also see Agyei-Holmes (2014).

Theme 1: Missing Histories: Why Have the 'Silent' Revolutions Not Been Seen or Heard about Earlier?

In recent literature references have been made to the spread of smaller-scale engines and associated equipment. Pearce (2012) remarked on the "hidden farmer-led revolution," and Giordano et al. (2012) wrote about small-scale irrigation technologies' being a "new" dynamic.

Therefore, we cannot but ask the question, Why have these revolutions been silent and below the radar, and why have they not informed national and international policy debates? The recent Vietnam history by David Biggs (2012) documents well how smaller engines have been spreading rapidly since the mid-1960s. In Bangladesh, the spread has been taking place since the mid-1980s and has been well documented for years. Other writers observed that different Green Revolutions of South Asia were brought about by the spread of smaller-scale irrigation and other rural equipment.[31] As early as the mid- 1970s, the senior Indian administrator Appu (1974) wrote an article for the widely read journal *Economic and Political Weekly* titled "The Bamboo Tubewell: A Low Cost Device for Exploiting Ground Water." The article contained many if not most of the lessons that are now being seen as part of the new and silent revolutions.[32] In Bangladesh, where it is estimated that more than 80 percent of tillage operations are mechanised, most of this has been done for many years by 2WTs, where rural entrepreneurs own the 2WTs and hire out the tillage custom services (Alam et al., 2004; Hossain *et al.,* 2013) So the question remains, Why has this evidence not been recognised? Although the economies of some regions of South Asia have been experiencing these changes, and the evidence has been documented and well recorded, in some circles these changes are now being treated as new and previously hidden. In some policy debates and agricultural and rural mechanisation R&D projects in different African countries, there is sometimes little reference to these Asian experiences of the spread of small engines and custom markets (Biggs and Justice 2015).[33] There are many explanations to our rhetorical question, and we will explore some possible

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[31] For example, see Molle, Shah, and Barker (2003); Mandal (2011); Rigg (2003); and Barker, Herdt, and Rose (1985); Shah, 1993; Shah et al., 2000; Kikuchi et al., 2003; Sikka and Bhatnager, 2005

[32] See Mukherji, Shah, and Verma (2009) and Pearce (2012). The question comes up again: why were lessons from Bangladesh, which were apparently relevant to India, not recognised earlier, when substantial empirical evidence was well documented since the 1980s and early 1990s?

[33] Two notable exceptions to this are the Farm Mechanisation and Conservation Agriculture for Sustainable Intensification project (FACASI), where concentration is on small engines and custom service markets, and the policy debates in Ghana (Diao et al. 2014).

answers here. We argue that unless the reasons for past and ongoing behavior are explored, then at best we are likely to come up with ineffectual policy rhetoric and practice in the future.

Theme 2: Characterisation of Small-scale Machinery

Biases in Official Data Reporting

Until recently, the Food and Agriculture Organisation of the United Nations only counted 4WTs as "tractors." 2WTs, if included, were often referred to separately as hand tractors, pedestrian tractors, power tillers, and garden tillers and did not count as "tractors." The same thing has happened in national data systems. This bias in official data collection procedures has helped to keep the spread of smaller-scale equipment out of sight. At the current time, with the spread of even more powerful 2WTs with engines in the 20+ horsepower range, and with 4WTs with engines of less than 15 horsepower spreading, there is clearly a need to look closely at official data collection methods.[34]

There is also a problem of under recognition of the spread of smaller-scale engines when they are used wholly or partially for "non-agricultural" purposes, such as for low-lift irrigation pumps, shallow tube wells, river boats, transport, milling, processing, forestry, and other rural activities (Steele, 2011).

Mis-characterised

Another problem with the official data collection is the mischaracterisation of the importance of the spread of smaller-scale equipment. Smaller scale is sometimes seen as the continuation and expansion of "traditional" equipment, where traditional is seen in a derogatory sense, and smaller-scale machinery is seen as a "transitional" stage to larger, that is, modern, large-scale mechanisation. Therefore, the smaller-scale equipment, even if useful for a while, does not count. The notion of smaller-scale machinery as merely transitional does not track with the experience from Southeast Asia and China.

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[34] Clearly, organisations like FAO know there have been data collection problems, and there is a need to assess current rural mechanisation issues. This was one of the rationales for an FAO agricultural project to review these issues in 2009. The book has now been published (Kienzle, Ashburner, and Sims 2013). At the time Peter Steele wrote a report ("Agro-mechanisation and the Information Services Provided by FAOSTAT") specifically on the data collection, reporting, and analysis issue (Steele 2011). In 2011, FAO and the UN Asian and Pacific Centre for Agricultural Engineering and Mechanisation started preparing a report titled Status and Future Strategy of Sustainable Agricultural Mechanisation in Asia and the Pacific. This is a challenging and important project in a rapidly changing global economy. It is hoped that the country studies and global analyses will be available soon and cover, in addition to technical issues, an economic, social, and political analysis concerning the relationship of different patterns of rural mechanisation to such national economic goals as rural development, food sovereignty, rural employment, trade, energy, and the environment.

Even with the rapid growth and spread of 4WTs, the 2WT industry continues to grow, albeit at a slower pace in Thailand (Thepent 2011) and China (Wang 2008).

Mis-understood, Mis-reported, and Mis-represented

One of our best examples of the misreading of smaller-scale mechanisation at the moment is the spread of lay-flat irrigation pipes in South and East Asia. This widely used and inexpensive technology may well be one of the most important innovations in irrigation technology in the past 15 years. Where it is common, it is treated as if it has always been present. However, in both Nepal and Bangladesh, we find there are few articles written about it or programs to promote its spread in regions where it is not common.

Furthermore, there are plenty of examples of pockets of resistance that still exist in some universities and in policy discussions that either deny its existence or trivialise its importance.

Another example of misrepresentation is when 2WTs are presented as if they have no more than 5 to 8 horsepower, when in fact the 2WT engine can be of 20 or more horsepower- larger than many of the small Indian 4WTs like Captain Tractors and even the 16-horsepower Yuvraj models from Mahindra and Mahindra.

In some discussions of tube well and low- lift pumps, there is a misunderstanding of the differences between centrifugal and axil flow pumps, and between shrimp-tailed propeller pumps and axial flow propellers (they are the same). Care is not always taken to distinguish lift levels in axil flow discussions or whether the discussion concerns electric, diesel, or petrol engines for pump sets.

Minor Status in Policy Debates

Smaller-scale mechanisation is often relegated to a minor and inferior status in irrigation policy discussions and in the institutional setups of government structures. For example, the term “minor” irrigation is used to describe smaller-scale groundwater and low-lift pump irrigation when in fact the smaller-scale equipment might be the most important and carefully managed source of irrigation water. This is true for both Nepal and Bangladesh where shallow tube wells and pump sets come under the lightly funded Minor Irrigation Divisions of the Departments of Irrigation. In large canal irrigation situations where conjunctive use of water is expected, the main canal management often takes priority over the smaller-scale equipment, such as low-lift pumps from the canal or groundwater shallow tube well irrigation, which might be useful in the same area.

Often, "appropriate," "intermediate," and "alternative" technology institutions and activities are not part of mainstream technology policy discourses. Labeling some technologies in this way has been a method for excluding some technical choices from policy consideration.

Misplaced Authoritative Knowledge

Finally, we need to mention the problem of misplaced authoritative knowledge, for example, where Bangladesh and Nepal officials are not aware, or deny the importance, of lay-flat irrigation pipes or where technical consultants and professional staff of aid agencies have little relevant knowledge. These are general issues that are well discussed in the aid literature and are not our focus here. However, in the case of the spread of smaller-scale irrigation equipment and 2WTs, we have seen that the plans and strategies of aid projects have not been informed by long experiences in South Asia where this type of equipment has spread. For example, in mid-1990s Nepal, the Agricultural Perspective Plan, drawn up with support of the ADB explicitly excluded consideration of any motorised rural mechanisation. Even today, some aid agency staff and consultants appear to be unaware of South Asian experiences and knowledge concerning smaller-scale equipment. As recently as 2012, there was almost disbelief among senior agricultural aid officials when we suggested that more than 80 percent of all tillage operations were mechanised in Bangladesh, and this was mainly by 2WTs.

Theme 3: Biases for the Promotion of Larger-scale Equipment

There is a whole range of arguments- often unsubstantiated- that is biased toward larger-scale equipment.

Claims of Efficiency: Engineering Efficiency in Large-scale Agriculture

In any analysis, it is difficult to factor out the "technical" efficiency of larger-scale operations from the benefits due to subsidies, influence, knowledge, and power in markets, whether this be through lobbying power or access to latest information. In addition, large-scale agriculture might appear technically and economically efficient, but the assessments change when sustainability of the long-term use of resources and other positive and negative externalities are taken into consideration.

Size of Holding

Academic debates on the efficiency of different size holdings have a long history and were the centre of much discussion in the 1970s. Some of those debates concerned the rationale for institutional reforms in rural areas, such as distributive land reforms, land ceiling acts, and measures to support less powerful rural people who could not have access to credit, markets, and relevant technical information. Although most information supported the idea that smaller holdings were more efficient than larger holdings, unsubstantiated claims persist for the technical efficiency of larger-scale equipment.

Assertions that Productivity in Rural Areas Can Be Increased Only with Larger Holding Size, Land Consolidation, or Both

It is difficult to understand the almost universal mantra in some policy circles and technical consultancy reports that small holding size and fragmented plots are central problems. Indeed, the notion runs in the face of the national empirical evidence of Bangladesh where agricultural productivity has been steadily increasing as size of holding has been decreasing. In 1983/1984, the number of marginal farms with less than 0.5 acres was 2.4 million, and in 2008 this had risen to 4.1 million holdings. The number of farms with more than 7.5 acres dropped from 0.5 million in 1983/1984 to 0.2 million in 2008. During the same period, average farm size dropped from 2.00 acres to 1.26 acres (Mandal, 2011). The smallholder agriculture of other regions, where smaller-scale equipment has spread, also has seen increases in productivity.

The Punjabi model of the Green Revolution, characterised by the spread of high-yielding varieties and the use of 4WTs in the 30- to 70-horsepower range, irrigated by large canal irrigation or large highly subsidised deep tube wells, and harvested by large combine harvesters, is still promoted by many as representing the only Green Revolution model. David Biggs (2012) reported that in Vietnam in the 1960s, American agricultural advisors were preoccupied with the promotion of the US family farm and the 4WT model of agriculture. The experiences of Bangladesh, Vietnam, Thailand, and Sri Lanka show that there are many types of Green Revolutions as regards patterns and scales of rural machination. [35]

[35] See Harwood (2012) for a recent history of different Green Revolutions that goes back to some of the early European experiences. In this paper we do not include an analysis of the Chinese history and contemporary situation and refer readers to such works as Yang, et al. 2013, Zhang et al. 2015, Wang 2008 and 2013.

In a recent study from the International Food Policy Research Institute (Zhang et al. 2015), the authors argue that past and current academic advocates of larger holdings (Pingali 2007; Ruttan 2001) do not take sufficient account of opportunities and evidence arising from custom markets in rural mechanisation processes. We argue that, in addition to service provision from large combine harvester service providers (their case study), there also has been a neglect of analysis of the widespread markets of service provision from small farmers and other small scale rural entrepreneurs selling services from smaller engines.

Global Reports on Future Food and Agriculture

Another source of bias against smaller-scale equipment comes from media presentation of global food and agriculture. Even when small-scale agriculture is included in the discussion, the report is often accompanied by photographs of fleets of combine harvesters and seeders drawn by large 4WTs working across large, flat landscapes. Rarely do we see pictures of smaller-scale mechanisation of the type we have been discussing here. It is hardly surprising that some policy discourse is informed mainly by such information.

Multinational Corporation Activities

Another source of bias toward larger equipment is multinational corporations in search of markets for their products.[36] Often these large institutions have the position and power to advertise, provide information, provide credit, and lobby for their interests. Sometimes they invoke the arguments of efficiency and suggest that "their way is the only way." As can be seen in the earlier mentioned Afghanistan example, often senior agricultural leaders and planners in ministries and departments view modern agriculture in terms of large-scale equipment and thus are sympathetic to the vision promoted by the multinationals.[37] The pairing of multinationals and policymakers in the agriculture sector has a long history that persists today. For example, in Nepal, multinational companies continue to open up sales and promotion offices at the same time that the Agricultural Engineering Division of the Nepal

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[36] See AgriEvolution 4th World Summit on Agricultural Mechanisation, December 5–6, 2013, Federation House New Delhi (http://www.cema-agri.org/event/agrievolution-4th-world-summit-agricultural-machinery; last accessed April 29, 2014). The event was hosted by FICCI (Federation of Indian Chambers of Commerce and Industry), where many major agricultural machinery multinational corporations such as AGCO, CNH International, Mahindra and Mahindara, and other Western agricultural organisations from around the world discussed trends they would like to see in developing countries.

[37] A recent study of the promotional activities of international agricultural machinery corporations and the dilemmas faced by local policy analysts is well described in Agyei-Holmes (2014).

Agricultural Research Institute and Agricultural Engineering Directorate in Nepal's Department of Agriculture are marshaling their few resources in an effort to obtain and promote machinery that is more relevant to the smaller holdings of much of Nepal. Even though 2WTs account for most of the tillage operations in Bangladesh, there are yet again moves to subsidise and find public-sector support for 4WTs there.[38] We are not suggesting that larger equipment does not have a place, but the current lobbying and promotion on the part of the multinationals needs to be weighed up against past empirical evidence and information from other sources.

Research and Teaching in Engineering Departments Biased toward Larger Equipment

The ideals and aspirations for future mechanisation encountered in engineering and agricultural research and teaching departments often mirror the biases of the government agriculture/irrigation agencies' leaders mentioned above. Although a comprehensive review of this issue is beyond the scope of this paper, the research and training of engineers has an important influence on rural mechanisation policy and practice. The influence of professional training goes beyond national agriculture institutes into the international agricultural research centres and donor agencies. Interesting to note, while financial and professional rewards have been more associated with the promotion of larger equipment, the major spread of the highly successful smaller-scale equipment appears to have come about in some South Asian countries without much support or inputs from formal engineering departments.

Theme 4: Promotion of Simplistic and Often Un-empirically Based Institutional Models for Smaller-scale Machinery

The last theme concerns the promotion of simplistic institutional models in association with different types of equipment. For example, to benefit from economies of scale, governments or other promotional organisations encourage the formation of rural self-management groups or cooperatives, often with a 50 percent subsidy on the capital cost. Groups are sometimes recommended because fragmented or smaller holdings are seen as a problem.

[38] International Development Enterprises (2012) shows that although the smaller 2WTs give a total repayment on investment in less than two years, various members of the 4WT lobby are expecting investment cost subsidies and other types of support such as special bank loans. It may be that some large holdings want 4WTs, but it is hard to make a national policy case for subsidies for larger-scale equipment.

Shallow tube well groups are a good example of such a model. They have the additional problem that cooperative assistance has a feel good factor over providing assistance for shallow tube wells and pumps to individual farmers. On other occasions, government or cooperative tractor hire schemes are recommended. The problem we see here is that these types of institutional models are extremely difficult to implement unless the broader social/political structural contextual issues are adequately addressed at the same time. Elite capture and bad management are frequent outcomes of past activities. By the same token, the advocacy that free market institutional models are the way to go is equally simplistic and does not take into account that the playing field for poorer people generally is not level as regards access to information about equipment, credit, or advice. Our point is that in the promotion of equipment to benefit poorer people, the policy discourse is often full of simplistic institutional models, with little reference to the way smaller equipment has spread in the past. Much of the experience of the spread of smaller-scale equipment in South Asia indicates that economies of scale issue were addressed in institutional models where markets in services have been encouraged. It is almost as if tractors and pump sets, large or small, will miraculously appear, be maintained, and even be locally produced, and cooperation and coordination between energy and irrigation ministries can be achieved, through regular coordination meetings. We suggest that there is a simplistic engineering bias underlying rural engineering policy discussions on relevant institutional models at the micro and macro level. The engineering bias is generally a greater problem for the encouragement and promotion of smaller-scale equipment, and relevant and viable institutional models, than it is for privately owned large-scale equipment.

Way Forward in Policy Analysis

Topic 1: Recognition of the Centrality of Local Conditions

Our first lesson is the need to recognise the centrality of local, time-specific conditions at the micro field/village level and at the policy macro level. Simplistic generalisations for the scaling out and scaling up of techniques and institutional models, while often part of many policy/project initiatives, are not based on the experiences of the spread of smaller equipment in some Asian countries.

Our own field-level experiences of the diversity of local soil and water management situations in Bangladesh and Nepal make this lesson apparent. If one adds to this the complexities of agrarian structure, cultures, migrant activities, social position, and economic situations, it becomes clear that the analysis of local conditions is central to serious policy discourse. At the macro level, Bangladesh with its gas reserves is in a different situation from Nepal with its underutilised hydroelectricity potential. India's energy policy concerning support for different patterns of electric (coal) and diesel engines for groundwater irrigation is a local issue for the India government. In Bangladesh the presence or lack of presence of arsenic and other groundwater quality issues is a localised problem at the national, regional, and local levels. Suitable legislation concerning the use and maintenance of groundwater aquifers is an especially important area of regulation- whatever smaller- or larger-scale tube well equipment is involved. The historical context is also important. For example, the histories of subsidising richer and/or poorer cultivators in poor rural areas affect expectations regarding future subsidies. Institutions and policy practice in each country are always changing. It should be noted that we are not saying that everything is complex and too complicated to make policy decisions. In fact, we are saying the opposite.

Overall policy must be country specific. The transfer of policy prescriptions/models from outside, especially outside the region, should be viewed with caution and skepticism.

At a pragmatic level, if you were to ask us to identify the priority agronomy/agricultural mechanisation policy issues now in Bangladesh and Nepal, we would say they are technologies that address labour shortages, especially seasonal demands and large labour spikes, and technologies that reduce drudgery. Examples: (1) rice-harvesting machinery such as 2WT, 4WT and self-propelled reapers; (2) threshers and mini–combine harvesters; (3) alternative rice crop establishment technologies, and (4) direct seeding technologies such as seed drills, specifically reduced-till, non-puddled, and zero-till conservation agriculture seeders and planters. To these would need to be added concerns with water and energy management.

Topic 2: Leveling the Playing Field in Rural Mechanisation

The second area concerns the leveling of the playing field for the creation and dissemination of information on smaller-scale rural mechanisation processes. We have shown that during the past 50 years in parts of South Asia, smaller-scale equipment has been spreading rapidly and increasing the intensity of the use of agricultural and other rural resources. Symptoms of increased intensity are increased cropping intensities and yields; careful use and management of soils, fertilisers, and water; and local processing of products. However, the data that are being promoted on growth still do not include this evidence about the role of smaller-scale equipment. Therefore, there is a need to integrate information and evidence about smaller-scale Mechanisation into policy debates. While situations will vary, some measures that might be considered are the following:

1. **Research and Policies that Promote and Regulate Local and International markets.** The case of Bangladesh shows that since the late 1980s there has been a pro-market trade policy for the import of capital/intermediate goods such as inexpensive, lightweight, multipurpose, and good enough Chinese diesel engines. India appears now to be adopting that strategy, as the sales of Indian smaller-scale equipment powered by Chinese engines is expanding rapidly.
2. **National and International R&D Organisations.** We referred earlier to the closing down of agricultural and rural engineering institutions in the Food and Agriculture Organisation of the United Nations, CGIAR, and other organisations. Now is the time to reconsider the rationale for those decisions, especially in light of current global policies to promote value-added chains. The development of suitable smaller-scale technology can be justified not only on equity grounds for the distribution of value added in the chains but also on efficiency in overall economic growth.[39]
3. **National Technology Use Surveys and Policy Analysis.** One of the reasons this paper remains illustrative is that it is hard to find data sets that can provide the information necessary for conducting an overall policy analysis on rural mechanisation issues. Different agencies collect and keep data for different purposes. The numerous problems with definitions have been covered elsewhere.[40] In addition, mechanisation is a fast- changing area; data might need to be collected quickly in a cost-effective way. Census data and regular national samples surveys frequently do not contain the details needed for this area of policymaking, and thus cost-effective supplementary surveys are often needed. We suggest that attempts such as the International Development Enterprises data we presented here would be a useful start as regards national figures. The data can always be enhanced once the process of this type of analysis is established. A second

[39] For more details see Biggs et al. (2011).

[40] See Biggs, Justice, and Lewis (2011); Justice and Biggs (2013); and Steele (2011).

dimension of data collection and analysis is the importance of cost-effective field surveys to identify what is actually happening in the field.[41] As we have discussed at length, there is almost a free for all now in international arenas of rural mechanisation, where lobby groups, specialist academics, and epistemic communities all promote their own knowledge and products.

4. **Selective Time- and Location-specific Equipment R&D.** In spite of the mixed history of applied problem-focused public-sector R&D, it still has a significant role to play, especially in agricultural/rural mechanisation. Given the successes and failures of the past, perhaps we need to be more skeptical of the content of R&D proposals as they are produced for many purposes and audiences. In keeping with our suggestion of avoiding generalities, we recommend that the ongoing technical research in Bangladesh examine the efficiency of axil flow pumps, the impact on wage labour of combine harvesters, and the yield and economics of replacing manually transplanted rice with mechanical transplanting or non-puddled direct seeded rice. All these are examples of the type of applied rural engineering research that needs funding.

5. **Action Research to Investigate Alternative Techniques and Institutional models.** There is a role for action research as long as it is recognised from the start that the very experiment represents a position along a policy choice agenda. For example, in Nepal there is an action research agricultural mechanisation project supported by a major Nepalese airline, Buddha Air. This research is looking at the viability of joint management where larger and smaller tractors and other equipment are shared. Part of the rationale of the project is that to gain economies of scale from equipment, there needs to be a joint management of the equipment. Another action research project might just as easily look at providing credit to small and/or tenant farmers to buy 2WTs and sell custom services. The 2WTs can then be hired out to neighboring farmers for tillage, threshing, transport, and a whole range of other activities.[42] The

[41] We are concerned here not with conventional long-term data collection surveys or with monitoring and evaluation activities of a project for which there is a large literature on practice. We are proposing special purpose surveys to actively seek out specific information about a specific topic. Bangladesh has a long history of such quick, rapid, informal, reconnoiter, innovator surveys going back to the mid 1970s. For an example, see Yunus and Latifee (1975). At the time, other groups in other parts of the country were carrying out similar surveys under the umbrella of the Ministry of Rural Development.

[42] For an example of this type of credit program, see the BRAC/Central Bank of Bangladesh Tenant Farmers Development Project (BRAC 2012).

second part of action research, which is always problematic, is translating the information gained into information that is relevant, useful, and effective in the broader economic and policy sense.[43]

6. **Information, Credit, and Fair Markets for Poorer Rural Entrepreneurs.** Two-wheeled tractors have shown themselves to be a profitable investment in Nepal and Bangladesh for many years. It is rare that the total payback period was more than two years.[44] Credit normally comes from personal or family sources. While poorer people need access to formal credit, there has been no provision in the formal banking system in Nepal to provide credit to buy such equipment, unless the client has land or other assets to mortgage. It is a situation where a special provision is needed in the formal banking system to make loans available to the smaller entrepreneurs for the purchase of smaller- scale equipment. Gaining access to reliable and relevant information is also an issue. Although the Internet provides a profusion of alternative choices, accessing and validating the information and then obtaining the equipment is often a formidable task for a poor rural woman with a small amount of potentially irrigable land in the western mountains of Nepal and whose husband and son are away in the Middle East or East Asia. It is also a major challenge for government or donor agencies to try to address these issues in a cost-effective way.
7. **Field-based Research to Test Claims of Efficiency and Productivity of the Different Scales of Technology.** One of the ways to further open up the policy debates in this area would be to encourage and fund field-based research on different scales of technology. This would need to include research that also looks at the actual practice in the economy, such as the historical studies reviewed here.

Topic 3: Methods and Rewards for Collecting Information from Informal R&D

A policy lesson to come out of the spread of smaller- scale equipment is the importance of obtaining information about what is happening in the field and acting on the information in a timely manner. This is particularly important for rural engineering techniques and institutions as many useful techniques and institutions arise out of informal R&D in the practices of the rural economy.[45]

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[43] Sometimes called the "scaling up and scaling out" of research results.

[44] Other papers in this volume, relating to rural mechanisation in Bangladesh confirm this. See, for example, Hossain et al. (2013) and Ahmed (2013).

[45] We do not assume there will not also be informal research and development creating "undesirable" innovations.

An example of informal R&D is the flexible and inexpensive lay-flat hose pipe used for irrigation. It was rural artisans and farmers who "looked over the fence" and saw something that was potentially useful and created what we would argue is one of the most important new irrigation technologies in recent years. Although the lay-flat pipe is common in some areas, it is unknown in areas where it might be useful, efficient, and pro-poor. The recent spread of ice pop wrappers being used for cheap drip irrigation in North India is another example of informal R&D (Pearce, 2012). The bamboo tube well and water/energy markets in Bihar and Bangladesh water markets, both from the 1970s, are another two examples of how institutional innovation has taken place in the field. Sometimes the start was stimulated by formal interventions of the government, donors, and NGOs, and on other occasions it would be hard to say what the start was. In any event, the policy lesson is the importance of conducting rapid and cost-effective surveys to keep abreast of, and assess the outcomes of, informal R&D and what measures can be taken to capitalise on informal R&D innovation. Bangladesh has a long history of developing cost-effective methods for this sort of monitoring. For example, see the surveys by many organisations under the Ministry of Rural Development (Biggs, 1978; Yunus and Latifee, 1975). Cost-effective, informal R&D surveys by engineers and social scientists could provide key information for facilitating the spread of the new technology. We posit that these innovations are being used for a whole range of activities for which they may not have been formally tested and that a whole range of novel institutional models are evolving for their sourcing, financing, maintenance, and use.

Other informal R&D is being conducted by small-scale entrepreneurs from Nepal who are touring China agro-machinery markets and fairs for ideas and equipment. From this informal market exploration and finding small-horsepower mini-tillers five or six years ago, the mini-tillers are now spreading rapidly in the rural Terai and mountains. More recently, small businessmen have brought back from China half- horsepower mini maize shellers and manual maize jab planters to test in the market in Nepal.

Some of these informal R&D surveys might be directed at the more formal activities of government, donor, and NGO programs. Frequently, the monitoring and evaluation activities of these planned projects become preoccupied with monitoring the planned activities and outcomes of the project to ensure they are in accordance with the original plan. They are frequently less interested in the unintended but positive outcomes.

Paradoxically, in this regard, some donors in Nepal encourage pro-market solutions for developing irrigation but then conduct few cost-effective surveys of actual irrigation practices in the markets. Funding of smaller-scale projects with different types of equipment and institutional models should be encouraged; however, care needs to be taken to avoid privileging this type of action research as a primary source of innovation.

We see it as important that engineers use rapid assessment techniques for the collection of survey data. This type of research method is often lacking in engineering curricula. This creates a problem for policy discourse, as this type of field information is then either collected in a selective and ad hoc way or presented by social scientists. Both methods lead to difficulties for integrating the survey information into engineering policy discussions. We advocate strengthening of field survey training and practice in engineering schools.

Engineering equipment and institutions are proliferating in rural areas, such as mobile phones, solar panels and pumps, locally made or imported diesel-powered three wheelers, rain and water harvesting methods, and micro hydro. What we are calling for here is cost-effective and proactive surveys designed to capture data on these activities as they are unfolding in the field. The formal monitoring and evaluation mechanisms of data collection for projects and programs often are not designed to collect and act on this type of information in a timely way.

Topic 4: Growth of Rural Industries and Sector Linkages

Keynesian economic frameworks such as national (Leontief) input/output analysis help focus attention on the importance of (1) backward and forward linkages between different sectors in an economy, (2) the analysis of how the output of the national economy is consumed locally/exported, and (3) the country's relationship to international trade. The 2WTs and smaller-scale pump sets are intermediate (capital) goods, that is, they are not consumed themselves but are crucial for the production of other goods and services.

In the cases we have reviewed above, the spread of a specific type of good enough and cheap enough intermediate good has been central to the intensification of agriculture and the rural economy.

These are the single-cylinder diesel engines to power irrigation pumps, boats, tractors, tempos, generators, mills, and rickshaws. In Bangladesh and Sri Lanka, this mainly has been Chinese equipment. In Thailand, the dominant source has been local manufacture under license of Japanese and

Korean engines. The strong backward linkage from imports or local manufacturing sectors to the agricultural sector has been critical to the intensification of agricultural production. As we have shown, the smaller-scale engines are also important in many other sectors, for example, road and river transport, processing, electric power generating, and harvest and postharvest operations.[46] As intermediate goods, these engines have made contributions to many economic sectors. Local manufacturing and repair facilities also have been established that have provided local rural productive employment and strengthened a local, adaptable industrial capability. The growth of this import/engineering industry has been important to agricultural and rural economics in the South Asian countries we have examined.[47] Therefore, the lesson for agricultural growth policy is that the strengthening of relevant engineering capacities in backward- and forward-linked sectors is as important as any direct attention to the agricultural sector itself. Smaller-scale equipment in both the agricultural sector and the linked sectors results in a robustness, flexibility, and sustainability in the local rural economy that might otherwise be absent when larger-scale equipment dominates the rural landscape.[48]

The growth of the poultry industries in Bangladesh and Nepal is another example of the importance of strong sector linkages. In Bangladesh, it is not uncommon to find maize yields of 6 tonnes per hectare on small-scale holdings where 2WTs are hired in for tillage operations, careful fertiliser application by hand, followed by multiple irrigations from hand-bored shallow tube well and water lifted by 5-horsepower diesel pump sets. In Nepal, another example of a strong backward linkage development is the use by farmers, and other rural entrepreneurs, of inexpensive plastic lay-flat

[46] Much of the time, these engines have not been used for a specialised sector purpose, but the same engine is used for multiple services.

[47] Bangladesh studies that look at the nature of backward and forward industrial linkages in the context of agricultural and rural machinery see Mandal, 2002 and2013; Alam et al, 2004.

[48] There is a well-established literature on growth linkages, which we will not review here except to say that backward and forward linkages are not automatically strong and have not necessarily led to strong employment in the agricultural sector and in linked sectors. Whether linkages are strong or weak depends also on trade opportunities, patterns of land ownership, and other agrarian structures. For a review of these issues, see Hart (1993). We argue here that smaller-scale mechanisation has led to strong rural linkages and rural development. The importance for our understanding of rural change, and policy analysis of whether small- and medium-scale industries are treated as in the industrial or agricultural sectors, is a well-known problem in economics and was empirically illustrated by Falcon (1967). This issue has significance for our argument here because if smaller- scale rural entrepreneurs with smaller-scale engines and other equipment are treated as agricultural units, rather than as industrial or service units, then an observer will be missing many of the changes in economic growth, distribution of incomes, and economic capacity development taking place in rural areas. This is another illustration of how choices as regards data collection and presentation methods influence what is seen or not seen.

irrigation hose pipe for irrigation purposes. This led to the establishment of several Nepali plastic manufacturing companies (de Bont, 2014).

In light of the above evidence, our policy recommendations on linkages are the following:

1. To strengthen inter-sectoral linkages, albeit a difficult task as sectors are generally defined by government, donor, and NGO bureaucracies.
2. To support small-scale rural manufacturing and repair industries.
3. To support vocational education and training.
4. To introduce and strengthen courses on smaller-scale rural engineering concerns and field survey methods in engineering schools.

Topic 5: Energy and Water Prices and Machinery Equipment Subsidies

Overall, government energy policy (provision and pricing of alternative energy sources) is central to influencing future patterns of rural mechanisation and hence strategies for agricultural and other forms of rural development.

National policies need to take into account positive and negative externalities of national resources/common property use, such as the sustainable management of groundwater sources, arsenic problems, drainage, and flood control. These are conventional areas of public policy analysis.[49] We have noted how Keynesian input/output Leontief models can be used to analyse the energy and water management dimensions of national economic growth.

Topic 6: Path Dependence

The last topic we wish to address is how past policies affect the ability of policy actors to direct the economy in new directions. In economic analysis, this is seen as a path dependence problem in which the same technological trajectory is maintained when a national, economic analysis might suggest a different strategy.[50] One of the features that leads to path dependence is subsidies. For

[49] It is beyond the scope of this paper to discuss the way energy prices directly influence patterns of rural mechanisation and the efficiency of resource use in different countries and regions. The article by Shah (2007) well illustrates how cheap, subsidised diesel fuel leads to inefficient production practices and gives advantages to diesel engines over other sources of energy.

[50] It has long been argued that the plant-breeding institutions of the CGIAR network are caught in a path-dependent technological trajectory in which plant breeding is seen as the priority technological way forward in addressing agricultural problems (Hogg 2000). This paper supports that view by arguing that, without the rural engineering inputs, subsidies, and guaranteed prices to agricultural crops in some cases, the high-yielding varieties would not have been able to express their potential. However, this did not lead to a concentration on water management, agronomy, and other rural engineering issues but rather a preoccupation with funding plant sciences at the cost of other technological priorities such as smaller-scale rural mechanisation for agricultural intensification and rural development.

example, rural entrepreneurs and farmers delay the purchase of equipment because, even if a piece of equipment is profitable, it is pointless to buy it today if you can get to the head of the line and get it cheaper under a subsidy.[51] Recently, 2WT sales in Bangladesh declined as a result of the introduction of subsidies for them. Similarly, in the early 2000s farmers in Nepal nearly stopped purchasing diesel pump sets for irrigation for nearly two years because they were waiting for the return of subsidies that never came.

One of the ways of addressing this would be to conduct a policy analysis to assess the lobbying demands and needs of different groups for subsidies and other preferential treatment. The agriculture sector in most countries is generally protected and subsidised. In South Asia, different "Green Revolutions" were usually highly subsided with cheap energy such as urea and water. Not reducing subsidies when they can no longer be justified from a national policy perspective leads to path dependence. The analysis would also have to look at the dominance of different actors in professional positions in the academy, research institutions, and policy arenas and the way they promote path dependence.

Conclusions

In South Asian countries, the spread of smaller-scale equipment, especially that powered by diesel engines up to 20 horsepower, has been accompanied by the intensification of agriculture and other rural economic activities. The spread of small-scale equipment has resulted in widespread mechanisation of the agricultural sector. It also has been accompanied, in most cases, by some workers leaving rural areas and finding employment in urban areas and in the overseas remittance economy. In many areas shortages of labour at peak times have led to substantial increases in real rural wages.

In regions where smaller-scale mechanisation has taken place, there has also been a growth of rural industries and strong linkages with the broader national economy. Whether by design or not, it appears that markedly different patterns of smaller-scale rural mechanisation over time have led not only to agricultural production increases but also to broad-based rural and economic development. As these patterns of smaller-scale rural mechanisation have taken place in today's global economy, they cannot be portrayed by the proponents

[51] Which farmers get to the front of the line for limited subsidies is yet another dimension for policy analysis. The effect of agricultural mechanisation subsidies on the agricultural manufacturing sector is beyond the scope of this paper, but needs analysis.

of larger-scale commercial agriculture as an outdated romanticisation of smallholder agriculture.

It is our hope that there will be increasing interest in the “silent and hidden” revolutions of the spread of smaller-scale equipment and that broad-based rural development, such as worthwhile rural employment and careful and intensive use of water and energy sources, will again become important goals of economic development. There is now empirical evidence on a grand scale that shows it can be done.

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Chapter 3

Growth of Mechanisation in Bangladesh Agriculture: Role of Policies and Missing Links

M. A. Sattar Mandal

Introduction

Days are gone by when one would see the hapless ploughmen walking behind wooden plough drawn by a pair of bullocks tilling the fields under the scorching summer sun in Bangladesh. The popular beliefs as reflected in earlier literatures were that our small land holdings and fragmentation were serious drawbacks for adoption of machineries and extensive mechanisation of farming would lead to unemployment of rural population (Ahmed, 1965; Alim, 1974).[1] There was apprehension that widespread unemployment might even lead to social upheavals (Alim, 1974). Myths and prejudices are gone. Now any casual observer walking through the country side can see 80 percent of tillage and irrigation operations and almost the entire threshing of rice, wheat and other crops is done by machines. Small and medium farmers also buy irrigation pumps and power tillers primarily for their own cultivation and then also for hiring out services of their machines to other farmers under various contractual arrangements. As a result, a vibrant market for local service provider or rural entrepreneurs has developed to perform whole range of operations in Bangladesh and elsewhere i.e., ploughing, land preparation, transplanting, seeding, irrigation, weeding, spraying, harvesting, threshing and drying.

History of agricultural mechanisation is replete with rich literature about the nature and institutional pathways through which machinery development and

[1] Average size of cultivable holdings in mid 1960s was 3.1 acres and an average farm would have 6-7 scattered fragments of about 0.5 acre (Ahmed, 1965). Average farm size, measured by cultivated area, dropped to 0.74 acre in 2008 (BBS, 2008). While number of fragments per farm remains the same, size of each fragment reduced due to sub-division of plots resulting from law of inheritance. There is apparently no sign of physical consolidation of holdings.

its expansion took place in different socioeconomic settings (Mandal, 2002; Alam, *et al.* (2004); Biggs *et al.*, 2011; Krupnik, 2013; Justice and Biggs, 2013; Ahmed, 2014). This paper discusses the extent of agricultural mechanisation and the context in which mechanisation has progressed in Bangladesh over time. Section 2 deals with changing structure of farms and labour market. Section 3 presents the growth of farm machineries and their use by different farm size groups. Policy changes and historical pathways to mechanisation are discussed in section 4. Section 5 discusses research, development and extension for mechanisation, while the section 6 identifies the missing links in mechanisation. Conclusions and issues of interventions are presented in Section 7.

Structure of Farms and Labour Market

Bangladesh had about 15 million farms and another 10.5 million non-farm households in 2008 in the latest year of agriculture census (Table 1). Number of farms has increased at about 2 percent per year between the last two census years, which means total number of farm holdings is likely to have increased already by another one to two millions at present. Over 84 percent of all farms have small land holdings of up to 2.5 acres and their numbers are increasing over time as the medium and large farms are being divided due to law of inheritance. Number of large farms operating more than 7.5 acres is declining too. Average farm size had declined from 0.8 hectare in 1983/84 to 0.5 hectare in 2008, indicating further decline by now. Each farm has 3.2 fragments of 0.16 hectare size demarcated usually by raised boundaries (*ails*) which, however, do not cause any serious practical problem for machine operation. Since all farms are fragmented, machine operators have learnt how to internalise the physical distance between plots of different farmers by scheduling field operations in such a way that maximum coverage can be ensured. This can be called 'operational consolidation' of holdings which actually becomes more effective through machine custom hire service or even contract farming by commercial enterprises.[2]

Like in many countries of Asia, agricultural labour market in Bangladesh is becoming tighter. Between 1999/2000 and 2010, although total agricultural employment increased by 29 percent, employment of male labour dropped by

[2] Syngenta's piloting of rice transplanter from seedling raising to harvesting, and Department of Agriculture Extension's demonstration of 10 acre block farming covering land preparation to harvesting by machines are two examples of operational consolidation of small holdings.

Table 1
Changing Structure of Farms

Farm Holdings	**1983/84**	**1996**	**2008**
Small farms (0.5-2.5 acres) million	7.07	9.42	12.53
Medium Farms (2.5-7.5 acres) million	2.48	2.08	2.11
Large farms (7.5 acres+) million	0.50	0.30	0.23
All farm hh, million	10.05	11.80	14.87
All non-farm hh, million	3.80	6.00	10.48
Cultivated area (‘000 ha)	8522	7192	7614
Av. Farm size (ha)	0.81	0.60	0.50

Source : BBS, Census of Agriculture, 1983/84; 1996; 2008.

6 percent in agriculture and rose by 54 percent in non- agricultural activities. Surprisingly, this loss of employment of male labour has been more than compensated by a staggering rise of 176 percent in female labour employment in agriculture (Table 2). Simultaneously, both male and female labour swelled up in non-farm employment. The obvious scarcity of agricultural labour, especially in short peak operation periods, has pushed up agricultural wage rates at about 26 percent per annum during the last ten years from 2005 to 2015, although wages for female labour has been dismally (40 percent) lower than the wages paid to male labour in recent times (WFP, 2015).

Table 2
Changing Labour Market (15 yrs.+)

1999/2000	**Both (mil.)**	**Male (mil.)**	**Female (mil.)**
Total	**39.0**	**31.1**	**7.9**
Agriculture	20.0	16.2	3.8
Non-agriculture	19.0	14.9	4.1
2010			
Total	**54.1**	**37.9**	**16.2**
Agriculture	25.7	15.2	10.5
Non-agriculture	28.7	23.0	5.7

Source : BBS, Labour Force Surveys 1999/2; 2010.

Types and Growth of Mechanisation

Accepting that there were less than one thousand irrigation pumps and roughly 1000 tractors and tillers in early 1970s, one may wonder how many farm equipments of different types are available in Bangladesh now[3]. The numbers vary depending on the year of reference and the meaning one portrays in identifying particular items in the very wide range of equipment. Biggs and Justice in chapter 2 of this volume rightly mention how the term 'tractor' conjures up in many people's mind a tractor that is used for only agricultural purposes, overlooking that the 2W and 4W tractors are also used for transportation purposes. It is also equally true that many people in Bangladesh would identify a 4W tractor as ''tractor'' and a 2W tractor as ''tiller''.[4]

Let us first take the number of irrigation tube wells and pumps in use. The annual survey of Bangladesh Agricultural Development Corporation (BADC) shows 35,322 DTWs; 1,523,609 STWs and 170,569 LLPs in 2012-13 irrigation season (Table 3). While 70 percent of the country's net cropped area of 7.6 m ha is under irrigation coverage, 97 percent of irrigation is done by using mechanised devices, mostly STWs. When one takes into account electricity connections to 17 percent of total irrigation pumps or 36 percent of area irrigated by electricity, one would imagine considerable mechanisation efforts involved in installation, wiring, metering and related activities in rural areas.[5] Both diesel and electricity have modest subsidy. These machines are used not for irrigating only rice, but also wheat, maize, potato and vegetables.

Now we turn to other farm machinery used for land preparation and different crop operations. A recent road map exercise for agricultural mechanisation 2021, 2031 and 2041 by a BARC led 7- member Committee and 9- member sub- committee, which is under consideration of the Ministry of Agriculture, shows the estimated total number of engines used for agricultural activities as 2.5 millions (Ministry of Agriculture, 2016). Most prominent farm machineries include 0.7 million power tillers, 35,000 tractors, 370,000 threshers, 400 rice

[3] Mettrick (1976) mentioned aid agencies donated 162 tractors and 652 tillers to meet up the draft power shortage following 1970 colossal cyclone, but about a half of these machines became inoperative after 200-300 hours of operation. This also painfully demonstrates how absence of repair and maintenance facilities can fail to give expected results. Jabbar (1980) cites that government also cash purchased 450 tillers that time.

[4] This reminds the author of a new term ''turbine'' for electrically operated deep tube wells in Comilla region during his nationwide field work for IIMI sponsored minor irrigation study in 1994/95. In many areas of Bangladesh, farmers mean shallow tube wells as deep tube wells just because they draw water from underground.

[5] As a matter of fact, electrification to rural houses through grid line and household solar system is growing very fast, generating works for the growing number of rural electricians ; this is one important RNF activitiy.

Table 3
Growth of Irrigation Equipment

Machines	Decadal Growth	Numbers (2012-2013)
DTW	1981-90→12% 1991-00→1% 2001-10→4%	35,322 2,910 (Diesel) 32,412 (Elec)
STW	1981-90→52% 1991-00→16% 2001-10→8%	1,523,609 1,270,136 (Diesel) 253,473 (Elec)
LLP	1981-90→5% 1991-00→1% 2001-10→	170,569 159,713 (Diesel) 10,856 (Elec)

Source : BADC (2013): Minor Irrigation Survey report 2012-13.
Note : In early 80s, there were only 14,000 DTWs and 93,000 STWs, STWs cover 60% land.

transplanters, 500 reapers, 200 combined harvesters together with huge number of other small machineries that include 18,800 USG applicators, 1.3 million sprayers, 0.25 million weeders, 40,000 jute ribboner, 320 solar pumps, 15,000 maize sheller, 50,000 sugarcane crushers, 15,000 rice haulers, 2,000 dryer. Table 4 shows that density of some major farm machines i.e., 4W-tractor, rice transplanter, reaper and combined harvester per 1000 hectares is too low to make any impact. Alam (2016) also mentions an average of 1.58 Kw/ha installed power, which is also much lower than needed.

Before we leave this section, let us make some comments on the road map mentioned above. Ministry of Agriculture deserves compliments for so promptly responding to a recent workshop's recommendations for preparing an agricultural mechanisation road map in Bangladesh[6]. Very high level concerns of the government was earlier expressed with the conduct of a public hearing by the Parliamentary Standing Committee of the Ministry of Agriculture in Comilla during 17-18 February 2012 to press on formulation of evidence based recommendations for advancing agricultural mechanisation. The road map duly emphasises urgent need of expanding mechanisation to

[6] Minister for Agriculture's presence in the workshop on "Creation of Local Entrepreneurs, Development and Manufacturing of Agricultural Machinery Appropriate to the Country", organised by the Farm Mechanisation project- 2nd phase on 11 October 2015 signifies the importance that the government attaches to agricultural mechanisation.

cater to labour shortage at peak crop operations and to rising wage rates for accelerating production and also for harvesting crops quickly before they are damaged by sudden floods in *haor* of north eastern regions and low lying areas of southern districts. It underscores short, medium and long term targets for introducing Mechanisation of sowing, transplanting, harvesting, and conversion of Englebar to Rubber huller among other crop activities. Some of the suggested prominent strategies include strengthening of R&D, institutional reform, creation of rural entrepreneurs, and promoting custom hire services for machineries. However, one prominent observation made in road map is that there is a pressing need of on- farm pathways so that the farm machineries can easily move to the fields.[7]

Table 4
Density of Agricultural Machinery and Installed Power

Machines	**Number**	**Number/'000 ha**
Tractor	35000	2.32
Power tiller	700,000	46.42
Pump (DTW)	35,322	2.34
Pump (STW)	1,523,609	101.04
Pump (LLP)	170,569	11.31
Rice Transplanter	400	0.03
Reaper	500	0.03
Combine Harvester	200	0.01
Closed drum Thresher	220,000	14.59
Open drum Thresher	150000	9.95

Source : Alam, M. (2016).

One may wonder if there is any evidence that mechanisation benefits mainly the large farmers who can afford buying machines and have also larger farm area to utilise machine capacity more fully. Earlier studies showed evidence of higher control and benefits of DTWs, LLPs and power tiller mechanisation by the large farmers (Alam, 1974; 1974; Boyce, 1987; Jabbar *et al.,*1983). As the liberalisation of machinery import flooded the market since late eighties and

[7] When intensive road network development has significantly improved connectivity in the country side, the field walk ways are meant for movement of tractors or tillers from field to field. Indeed, lack of small culverts on khals and creeks limits machinery movement, especially in southern Bangladesh.

early nineties, small and marginal farmers' access to and benefits from STW irrigation and also from power tillers' use increased significantly (Hasan *et al.*, 1991; Hakim *et al.* 1996; Mandal, 2002; Alam, 2000; Alam, *et al.,* 2004). Alam *et al.* (2004) found that 60 percent of power tiller owners and almost all of the power tiller users in Keshabpur area of Jessore district were small farmers cultivating up to 2.5 acres and that investment in PTs proved profitable in terms of gross margin as well as financial analysis. The same study also revealed that spread of PT technology had increased incomes of a wide range of actors i.e., PT owners, operators, mechanics, spare parts suppliers, input and output traders through a large array of backward and forward linkages created in the rural economy. More recent results of IFPRI study presented by Ahmed in chapter 5 show that small and medium farmers used power tillers and tractors as much as large farmers through the spread of machine rental service market.

Policy Pathways to Mechanisation

A changing policy landscape is shown in Table 5. Historically, agricultural mechanisation in this country was conceived as a modern device for rapid tillage, land preparation and surface water irrigation by low- lift pumps (LLPs). In 1951, there were 100 tractors, by 1965 the number rose to about 200, all owned by the governments. Besides, some private organisations also owned a few tractors (Ahmed, 1965). Most of these tractors were of six makes and nine sizes; while four fifths of tractors were of conventional four- wheel type, one-fifth were of the crawler type, all ranging from 30 to 50 hp (Ahmed, 1965). Ahmed (1965) also writes that these tractors were mainly utilised for reclamation of about 70 thousand acres of waste lands by 1962 out of about 2.5 million acres of cultivable waste lands identified by a survey. These culturable waste lands including those in *haors* and *beels* were scattered in Chittagong Hill Tracts, Chittagong, Sylhet, Dinajpur, Rangpur, Kushtia, Faridpur, and Jessore regions of the country (Ahmed, 1965).

It is widely recognised that the first concerted efforts towards farm mechanisation came from the government launching the "Mechanised Cultivation and Power Pump Irrigation" scheme in 1950-51, through which diesel- run four- wheel tractors and small engines were introduced. Following the report of Agricultural Commission in 1962, which identified farm mechanisation as one of the five essential items of intervention, the government initiatives for mechanisation got fresh boost up (Alim, 1974).

The Agriculture Department took up many efforts to popularise use of improved farm implements through machinery exhibition, demonstration and group discussion with farmers at the local levels. Improved farm implements included improved ploughs, which did not go far due to unavailability of necessary bullock power (Ahmed, 1965).[8]

Table 5
Policy Changes Influencing Mechanisation

Period	Policy Features
1951-1974	Public Sector Initiation: Irrigation and tillage mechanisation; subsidised 380 – four cfs DTWs; 2 cfs DTWs, STWs and LLPs promoted through farmers' cooperatives
1974-79	Public sector rationalisation phase: pump rental stopped, STW subsidy reduced; liberal credit for STW purchases.
1979-84	Private sector expansion: STW engine import duties reduced; liberal credit, private sector gathered momentum, reduced public sector control.
1984-87	Reversal to public sector control: Ban on STW sales & embargo on engine import, imposed engine standard and pump spacing rules.
1987 onwards	Rapid expansion by private sector: Withdrawal of equipment import ban & spacing regulation; elimination of import duties & engine standardisation; credit & extension service extended.

Source : Adapted from Mandal and Parker (1995):

One report shows that 2,238 low- lift pumps, 200 four- wheel tractors and 13,828 sprayers were distributed to farmers by the government over the period 1960- 65 (Ahmed, 2014). The machines were provided against very low nominal fees whereas the users/owners arranged their diesel fuel at their own cost. As one would expect, these were captured by well connected local elite ffarmers, while the low- lift pumps were largely used by them to dry perennial water bodies (e.g., *beels* and *haors*) for growing local Boro paddy.[9] Some of the

[8] There was a recommendation to the government for an R & D project to improve animal draft cultivation by: (a) improving the health and strength of the animals; (b) implement design; and (c) attachment of the implements to the animals (Mettrick, 1976). In the backdrop of wide spread use of cows for ploughing, Jabbar (1980) urged for a mechanisation policy that should have an immediate objective 'to find ways of restoring the social position of the cow as the producer of milk'.

driving slogans during sixties and seventies were "grow more food" and "maximum production from minimum land".

In November 1970, a catastrophic cyclone that hit the southern region of the country caused deaths to huge number of cattle population and the loss was further accentuated by the slaughtering of 2.3 million cattle during the war of liberation in 1971 (Odend'hal, 1978). All these resulted in an absolute shortage of draught power in the country with the manifestation that 40-50 percent of power animals were female and the quality of animal was poor and deteriorating (Jabbar, 1980). Later on, it was reported that the draft power shortage in 1981 was 40 percent on an average and that it rose to as high as 70 percent in 1985 in some parts of the country (Maniruzzaman and Baqui, 1993). After the cyclone international charitable organisations donated 135 tractors and 569 power tillers to cope up with the draft power shortage in the affected areas.

With the start of Bangladesh as an independent country, the new government attached topmost importance to increasing food production for which seed-fertiliser- irrigation technology was given high priority in policy documents including the First Five year Plan (1973-77). One visible action was distribution of low- lift pumps (LLP), deep tube wells (DTW), and shallow tube wells (STW) for irrigation through a rental service programme by the state run agency Bangladesh Agricultural Development Corporation (BADC) which was responsible for assured supply of diesel and mechanic services.

Mechanised irrigation picked up mostly with STWs which were largely imported by the private sector from the beginning. But the government allowed only a few specified makes and models of Japanese diesel engines that operated the STWs. Such restrictions slowed down the pace of irrigation growth but these were lifted later on to allow private sector to import engines in response to increasing demand from the farmers. The import liberalisation policy of the government began since late 1980s. This opened up wide range of opportunities for private sector to import machinery, mainly cheaper diesel engines and two- wheel power tillers from China. By 1988/89, the number of STWs rose to 235 thousands from far less than 100 thousands in early 1980s.

[9] IRRI -HYV rice varieties did not yet come. The present author observed himself in his school days in early sixties how a local lead farmer from his adjacent village area in Faridpur region managed to get a low- lift pump which he used to pump out water from two beels (Gajaria beel and Masjidgaria beel) and grew local Jagli Boro rice variety in the drained beel land. He demonstrated low- lift pump use for the first time in the area and made wonder by harvesting huge amount of paddy in the month of March/ April when farmers' stock of rice generally dropped to a low level. Unfortunately, both the beels are completely dried now to grow HYV rice and also fish in ponds newly dug at the bottom of the beels.

This process of market liberalisation was further accelerated by the government's prompt response to address the loss of human and animal lives caused by the devastating cyclone in 1988. The mid- term review of the Third Five Year Plan estimated the draft power loss equivalent to 0.13 million tractors (Planning Commission, 1989).

Since late 1980s, large scale liberalisation of market took place mostly as a follow up an independent agriculture sector review conducted in 1987-88 in the backdrop of "slow down" in agricultural growth[10]. The move towards privatisation of minor irrigation included withdrawing duties on import farm machineries, waiving standardisation certification for machines, removing siting restrictions for irrigation tube wells and supporting private importers with liberal credit facilities, provision of foreign exchange allowance and related banking services (Mandal and Parker, 1996; Ahmed, 1999; Mandal, 2000; Gisselquist *et al.*, 2002). As a result, cost of STW engines dropped to below Tk 20,000 (US$ 600) which was about one-fourth of the price for Japanese engines that were permitted for import before deregulation (Ahmed, 1999). During 1989/90 to 1997/98, number of STW irrigation pumps jumped at about 20 percent per year and area covered by STW at about 14 percent per year (Mandal, 2000).

Ahmed (1999) illustrates how BADC kept experimenting with four-wheel tractor service since inception, but soon abandoned this due to inappropriateness of this machine. They did shift to power tillers and achieved success in allowing the private sector to import and deliver these. Although the domestic market for power tillers quickly developed, BADC did, however, kept control over import by allowing tax free import of power tillers of their approved makes and models. Only one model from China and another model from South Korea were allowed. All other models included in the BADC list were from Japan, the latter lost the market because of much higher price compared to the price of Chinese and Korean brands. According to Ahmed (1999), this was a classic case of oligopoly pricing allowing in effect the cheaper Chinese power tillers being sold at as high price as market would bear. With large scale privatisation policy being implemented since the late eighties, the market was flooded with various brands of two- wheel power tillers at significantly lower prices than farmers used to pay earlier

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[10] Ministry of Agriculture sponsored the Agriculture Sector Review in 1987-88 with support from UNDP at the backdrop of flagging growth rate of agricultural output and employment, especially per capita cereal foodgrain production declined.

This surge in power tiller market following withdrawal of import duty in 1989 is corroborated by this author's personal interview in November 2014 with Chittagong Builders, the largest sole importer of Saifeng and Dongfeng brands of power tillers from China since 1983. This importer also started importing 1- 30 hp three- phase electric motors for DTW irrigation pumping and then imported Yamaha and Kubota diesel engines for STW pumping in 1981. Although Japanese engine, which were of high quality, had been pushed with subsidy from the government in 1980s and 1990s, farmers were keen on buying less durable Chinese machines when they were made available because these were much cheaper and affordable. According to importers' business insights, subsidy did play some roles at the early stage of machine promotion, but more important had been the reliable delivery of machines according to farmers' choice (e.g., Saifeng power tiller for paddling clay soils and Donfeng power tiller for light sandy loam soils), and aggressive sales drive through efficient dealer network and TV advertisement for machines.

Research, Development and Extension for Mechanisation

The spread of farm mechanisation took a long time and efforts of government, R&D institutions as well as private sector machinery manufacturers and dealers. Numerous research findings and experimental results on mechanisation issues and opportunities were disseminated through many seminars and workshops in Bangladesh and south Asian region. An earlier IRRI publication on "Consequences of Small Farm Mechanisation" back in 1983 made a huge impact on understanding and policy implications for the type of farm mechanisation to be pursued in the Asian countries including Bangladesh. Two other notable academic initiatives include (i) BARC organised national workshop on "Agricultural Mechanisation- Its present Status and Future Strategy in Bangladesh" in Dhaka on 25-27 February 1992; and (ii) SAARC Agriculture Centre organised regional workshop on "Farm Mechanisation for Small Holder Agriculture in SAARC Countries" in Bhopal, India on 22-24 September 2008 with strong representation from Bangladesh (SAC, 2008). One of the earlier initiatives towards promoting agricultural mechanisation for crop intensification was the publication of a "Farm Machinery Resource Handbook" by the Canadian Assisted Crop Diversification Project under the Department of Agriculture Extension in 1994. This provided pictorial description of farm machineries together with the names and addresses of their manufacturers and dealers throughout the country. The seven categories of implements demonstrated in book included (i) tillage and land preparation equipment, e.g., tractors, PTs and improved ploughs; (ii) inter-culture, seeding and planting machines, e.g., seeder, rice transplanter and seed driller; (iii) plant protection equipment e.g., sprayer; (iv) water lifting and irrigation equipment, e.g., centrifugal pumps; (v) harvesting and threshing equipment, e.g., pedal and powered thresher, maize sheller; (vi) processing machineries, e.g., auto rice mill, Englebarg rice huller, Dal mill and oil expeller; (vii) Haulage and transport equipment e.g., tractor trailer.

A more recent initiative has been the publication of a "Directory of Successful Farm Machinery in SAARC Countries" by the SAARC Agriculture Centre in Dhaka in 2012 (SAC, 2012). This provides pictorial illustrations with details of a large number of farm machineries used in Bangladesh, India, Pakistan, Nepal and Sri Lanka. The directory is a useful source of hands on information for the manufacturers, researchers as well as policy makers at the country level.

A major institutional boost in agricultural mechanisation came through a project with the start of an Agricultural Engineering Wing under a project within DAE in 1997, which does not exist after the project ended. The engineering personnel now perform dissemination work for mechanisation through the mainstream DAE network at the field level. Currently, DAE implements a government funded five-year project on "Enhancement of Crop Production through Farm Mechanisation- 2nd Phase" for 2013- 2018. Major activities include popularising small-scale farm machineries i.e., power thresher, reaper, rice transplanter, PT operated seeder and small combined harvester through 30 percent subsidy sales. Mechanic training and machinery demonstrations are also provided by the project. As the PTs are already available in the market through the private sector, subsidised sale of tillers has been stopped. A point for note is that only an insignificant proportion of total sales of farm machineries are pushed through subsidy e.g., roughly 5,000 PTs out of an average 50,000 PTs sold per year. A recent trend of agricultural machinery service market is given in IDE (2012).

The major R&D of farm machinery in Bangladesh has been led by BARI, mostly with government funding and also with support from international organisations i.e., CIMMYT. Other prominent institutions involved in farm mechanisation R&D include BRRI and BAU. Private manufacturers like Alim Engineering, Metal, Corona groups, Janata Engineering and many others also got collaboration and technical advice from the lead institutions.

BAU-REFPI project with the support of DFID during 2000-2003 needs a special mention as it contributed immensely to research capacity building, training to manufacturer and mechanics, networking and dissemination of small- scale farm machinery. The rapid growth of local manufacturing and development of farm machinery market can be to a large extent attributed to the work of the REFPI project (see the chapter 8 on REFPI in this volume).

In terms of international collaboration for agricultural mechanisation, IRRI and CIMMYT played very significant role through various projects. CIMMYT's work with national partners has supported popularisation and demonstration of scale-appropriate farm machinery for resource conservation agriculture (Krupnik *et al.*, 2013). Cereal System Initiative for South Asia-Bangladesh (CSISA-BD) involving IRRI, CIMMYT and World Fish has facilitated demonstration of machineries for innovative cropping patterns incorporating new varieties through five hubs in Mymensingh, Rangpur, Barisal, Khulna and Faridpur. Especially, the development of Local Service Providers (LSPs) through machine supply, training, advice and networking is a significant contribution of the project (Mandal, 2015).

Before we move to other section, it is pertinent to mention the role of vocational trainings in the spread of rural mechanisation in Bangladesh. Out of a total 64 Vocational Training Institutes (VTI) 34 have been engaged in giving Secondary School Certificate and Higher Secondary Certificate level two- year courses which include a significant number of trade courses on farm machinery. There are also numerous private institutes that provide short training on machine operation, repair and maintenance. Many of these trainees are the ones who have taken up mechanic jobs as well as started small machinery spare parts shops.

Missing Links in Agricultural Mechanisation

Agricultural activities are done separately but these are planned as a sequence that needs mobilising acts well ahead. While irrigation, tillage and threshing operations are almost fully mechanised, there has been modest mechanisation of two important operations i.e., transplanting/seeding and harvesting operations. This is likely to make farmers' decision about planting difficult because the shortage of human labour becomes evident during these periods. This is the main reason that DAE mechanisation project now puts emphasis on dissemination of rice transplanter, power tiller driven seeders, walk behind reaper and where possible combined harvester. Although farmers are ready to adopt or adapt rice transplanter, their cost or technical feasibility with respect to varying soil conditions and farmer's choice of seedling age (mechanical transplanter needs very young seedlings put on trays) are not yet decisive. CSISA-BD field data shows only about Taka 1,000 per ha. (US$ 13/ha) lower cost of machine transplanting of rice as compared with manual transplanting, although average grain yield is higher by 0.6 t / ha in case of rice transplanter (CSISA- BD, 2015).

Another missing link is the expressed concern for establishing quality control and certification of machineries in any farm mechanisation forum. Ideally it may make sense, but the huge task of capacity building for machine testing and design of regulatory provisions towards a credible quality control are seldom made clear. Our concern is that quality assurance measures should not in any way discourage local manufacturing or importation of machines. Besides, there is hardly any serious discussion about development of machineries for use in livestock animal rearing, fish culture or fish processing, or in dairy farming[11].It is also noted with surprise that there is seldom any reference to the development of women friendly mechanisation despite the fact there are clear signs of increasing participation of women in field as well as postharvest agriculture.

Conclusions

There are a number of important conclusions that one can draw from Bangladesh. Firstly, policy of market liberalisation which allowed increasing participation by private sector has contributed immensely to the growth of mechanisation. Small farm holdings and fragmentation has not affected expansion of irrigation and tillage mechanisation or productivity gains significantly. Local entrepreneurs took up custom hire service for machineries, which has resulted in effective operational consolidation of fragmented holdings in practice.

Secondly, the transition to private import and distribution of agricultural equipment has not always been that easy or without resistance from interested groups which at times may maneuver policies to continue monopolistic control by the public sector.

Thirdly, and more importantly, only a sustained growth of crop sector, especially rice, resulting from rapid expansion of irrigation and power tillage services at farmers' level did convince the policy makers to continue to

[11] Only known example is making provisions for small- scale milking machines on a pilot basis in a number of government projects with Department of Livestock Services and Milk Vita.

support agricultural mechanisation through increased involvement of the private sector.

Fourthly, as the irrigation privatisation contributed to rapid expansion of rice cultivation in the dry season, it induced demand for quick tillage by power tillers and later on for reaper and threshers and so on.

Finally, agricultural mechanisation is seen as an integral part of rural mechanisation. Therefore, provisions of rural electrification and rural road and transport network are given crucial importance in successive Five Year Plans of the country. Development of rural townships has also been given priority because these support machine repair and mechanic services so badly needed for sustaining mechanisation. Increased budgetary provisions is recomended for sustaining maintenance of rurual road network.

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Chapter 4

Agricultural and Rural Mechanisation in Nepal: Status, Issues and Options for Future

Devendra Gauchan and Shreemat Shrestha

Introduction

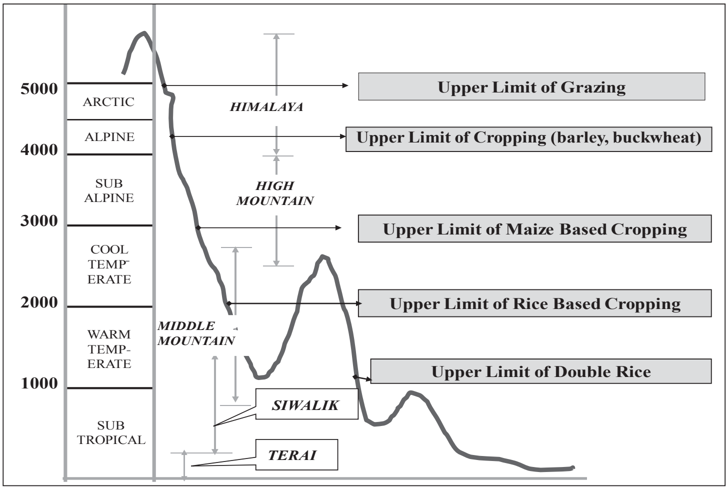
Nepal is a small land-locked mountainous country with diverse agroecologies, culture and agriculture. Agriculture is a key source of economic growth, poverty reduction and environmental sustainability in Nepal. It is the mainstay of the national economy, contributing one third of GDP and providing livelihood to more than two thirds of the population (MoF, 2013). The poverty rate is declining over the last two decades but it is still high with one-quarter of its population (25.1%) living below poverty line (CBS, 2012). Food crops are the major components accounting for about 40% of AGDP, while livestock and fishery account for 30%, horticulture and cash crops 20%, and forestry about 10% (MoF, 2013).

Agroecologies and Farming Systems

The country is divided into three primary ecological zones mainly running east to west: (i) the mountain region bordering Tibet of China covering high Himalaya and high mountains, (ii) the Hill region in the middle, and (iii) the Terai or plains covering inner (siwalik) and main Terai bordering India. The Mountain, Hills and Terai, respectively, covers 35%, 42%, and 23% of the total land area of the country (CBS, 2012). Each of the three main ecological zones has its own unique resource endowments, cropping patterns and farming systems leading to differences in commodities produced, production levels, and productivity. There is also a high socioeconomic diversity: with more than 100 ethnic groups with different culture, communities and economic conditions (large absentee landlords to landless tenant farmers) with diverse needs for farm machinery and equipments.

A high agroecological diversity exists in Nepal ranging from flat lowlands and rivers basin to rugged mid hills and steep mountain slopes with subtropical to warm temperate, cool temperate, and alpine to arctic type climates (Figure 1). As a result, there is a diversity and complexity of farming systems with adaptation to specific crops and commodities in specific altitudinal zones. Rice based farming system is predominant in Terai, inner Terai and lower part of mid hills, while maize based system is predominant in middle hill to lower part of high mountain region. In rice based system, double cropping of rice is only possible in subtropics below 1,000 msl in Terai and Siwalik (inner Terai), while single rice cropping is possible until 2,000 msl[1] in middle mountains where warm temperate climate is prevalent. The mountain crops such as buckwheat and naked barley is grown in high mountain region up to 4,500 msl, where climate is subalpine and alpine type. Pastoral production system with livestock grazing is possible in arctic climate upto altitudinal range of 5000 msl. Crop-livestock and forestry integration is the characteristic features in all these systems.

Figure 1
Diversity of Agroecological Zones and Farming Systems in Nepal



Agrarian Structure

The agrarian structures of the country are characterised by a very small land holdings scattered to different plots, where irrigation availability is very limited and seasonal. The average size of land owned by the household currently in Nepal is about 0.68 ha, which is highly fragmented, averaging 3.1 parcels with

[1] Exception exists in Karnali region, where rice is grown upto 3,000 msl in Chumchur of Jumla district.

average size of 0.21 ha per parcel (CBS, 2013). At present, about half (52%) of the farm households own less than 0.50 ha land with low farm labour productivity, and low level of intensification. Area under farming is declining over the years as a result of conversion of prime agricultural land into non-agricultural uses (e.g. housing, industries and infrastructure development) through rapid urbanisation and rural-urban migration. Hence, in the last 10 years, net cultivated area has declined by 5% from 2.65 million ha in 2001 to 2.52 ha million in 2010 (CBS, 2013). Average farm size has also declined over the years from 1.11 ha in 1961/62 to 0.68 ha in 2011/12. The number of households with 2 ha or more of land has decreased from 12 percent in 1995/96 to 4 percent in 2010/11. Moreover, two thirds of the cultivated area is rainfed, where agricultural production is risk-prone and marginal. A large proportion of farm households (30%) are employed only partially. About 60% of the households in Nepal have only six months of food sufficiency from their own production. Population density on cultivated land is high where more than 10 people are dependent on a hectare of land for their livelihood. Agricultural productivity and profitability from farming are low due to low use of modern and mechanised technologies, high cost of production, limited commercialisation and diversification of agriculture. Labour scarcity is chronic in agriculture as a result of massive youth migration from rural areas.

Importance of Agricultural Mechanisation for Nepal

Agricultural mechanisation is being recently realised by policy makers and planners as one of the potential options for addressing agricultural labour scarcity, high cost of production and promoting commercialisation in agriculture. Mechanisation is also an option for improving efficiency in agriculture production, reducing women drudgery and promoting diversification in agriculture. Mechanisation saves costs and resources (labour, energy) by reducing operational time in agriculture and improving timely farm operation. It helps make agriculture competitive in the region by reducing the cultivation cost, improving quality of the products and creating conducive environment for the competitive market price of the produced agricultural commodities. The rationale for mechanisation in agricultural development is to increase the scale of farming operations and to improve the timeliness, quality, and efficiency of the operations for increase production, productivity and profitability of farming operation. Mechanisation, therefore, can contribute to increasing production, productivity, and profitability of agriculture by increasing land and labour productivity as envisaged in

Agriculture Perspective Plan (1995-2015) and newly formulated Agriculture Development Strategy (2014) of the Government of Nepal.

Evolution of Agriculture Mechanisation

The history of institutional development for formal sector farm mechanisation dates back with the establishment of Agricultural Implement Research Unit at Birganj in 1960 (MoAD, 2014). Since early 1960s, private sector played important role in farm mechanisation with the import of four- wheel tractors (4WTs) for agricultural production and transport in the Terai (Pudasaini, 1976). Since 1970s, mechanisation picture has changed significantly with the spread and use of threshers (in wheat and rice) and diesel pumps in farm irrigation. Two-wheel tractors (2WTs) were promoted during the mid-1970s and early 1980s, with two Japanese aid programmes importing approximately 2,000 tractors (Pariyar *et al.*, 2001). Initially, the spread of 2WTs was limited to the Kathmandu and Pokhara Valleys, where they were used for transport and tillage (Biggs *et al.*, 2011). Tractors are common in tillage and transportation of agricultural products, while combine harvesters are increasing being used in harvesting. From the mid 1990s onwards, large Indian combine harvesters were seen in Nepal, and today about 200 Nepali combine owners work on a contract basis in various districts in the Terai, majority of which are concentrated in Rupandehi, Bara, Parsa, Rautahat, Kapilvastu and Kailali districts. Mechanisation technologies and machines available across the long open border with India greatly influenced mechanisation patterns in the Nepal Terai (Biggs *et al.,* 2011; Justice and Biggs, 2013). With increasing road connectivity in rural hills and mountains, use of tractors, power tillers, pumpsets and threshers is increasing in rural hills and mountains as well. At present, the most widely used farm machineries are threshers and small scale irrigation pumps that are becoming popular in most parts of the Terai and market accessible hills because farmers see a clear advantage of using machineries in terms of saving time, resources, and labour. In addition, mechanical equipments are increasingly being used in the rapidly growing horticultural, poultry, dairy and animal feed industries and other "value added chains", mainly through private sector initiatives based on agricultural and other rural resources.

Status of Agriculture Mechanisation

Use of farm mechanisation is currently very low in Nepal. Official statistics show that animal and human power are still major sources of power used in agriculture, which constitute about 41% and 36%, respectively. Use of machine power is estimated to be only about one –fifth of the power used in Nepal (AED, 2013; Shrestha, 2012). About 90% of the currently used mechanical power is concentrated in market accessible Terai. In the hills and mountain districts, mechanisation is low given the difficulties of transporting heavy machinery and using it on small terraces. However, with increasing road connectivity in rural hills and mountains, use of tractors, power tillers, pumpsets and threshers is increasing in recent years. In the last five decades, some progress has been made in agricultural mechanisation in Nepal with various types of machinery being adopted, primarily through imports by the private sector and its engagement with farmers. These include several power-operated agricultural machines including the following: water pumps; tractors both 4 wheel and 2 wheel; harrows; rotavators; seed drills; threshers; combine harvesters; agricultural processing machines; rice, oil, and pulse mills; and laser land-levelers particularly in Nepal Terai (Biggs and Justice, 2013).

The data of national sample census in agriculture revealed that most common agricultural machinery used in agriculture includes iron ploughs, tractors and power tillers, thresher, pumping sets, sprayers, shallow tube wells, etc. (Table 1). Animal drawn carts, and treadle pumps (*Dhiki*) are also in operation in Terai. As per the recent national census in agriculture (CBS 2013), the percentage of households using iron ploughs, tractors and power tillers, thresher, pumping sets and shallow tube wells constitute about 28%, 24%, 21%, 14 %, and 9%, respectively. In Nepal, mechanised equipment has also spread, but this does not appear to be so focused on rural poverty reduction, rural employment and productivity increasing (Justice and Biggs, 2013).

In Nepal, about 76 thousand four-wheel tractors are registered till 2011. It is estimated that about 22,000 power tillers and about 5,000 mini tillers are in operation in Nepal (AED, 2011). But not all of these are used in agriculture. It is estimated that about 30 % of the registered tractors and above 80% of registered power tillers and 100 % mini tillers are actually used in agriculture. A large proportion of tractors are used in non-agricultural purposes, including use in rural transport, construction, sand mining and quarrying industries. According to 2010 estimates, there are 120,000 pump sets, 190,000 threshers, 10,000 mills 190,000 threshers, and 40,000 hand cranked winnowing fans (MoAD, 2012). A most recent estimate shows that there are about 200 combined harvesters operated in Nepal Terai. Similarly, in the livestock sector, commercial dairy farming has increased with increase in use of machinery in milking, storage, cooling and processing technologies associated with dairy. Information also shows that there are more than 200 thousand biogas plants being operated resulting in increased rural energy use in agriculture. Recently two- wheel tractors are increasingly being popular in Nepal particularly in the market accessible hills and mountains with the increased road connectivity and labour shortage. In the Terai region also there is increase in the use of two-wheel Chinese tractors apart from existing use of four-wheel ones, mostly Indian tractors. Similarly, mini tillers have also increased owing to their compatibility to small land holding size, especially in the hills. The trend of mechanisation is apparent and will be helpful to lift agricultural productivity in several regions of Nepal.

Table 1

Households Using Different Types of Agricultural Machineries in Nepal

Machinery/ Equipments Used	No. of Households	Households (%)
Iron ploughs	1,073,441	28.02
Tractor & Power tillers	920,371	24.03
Thresher	803,154	20.96
Pumping sets	548,203	14.31
Sprayers	574,014	14.98
Shallow tube wells	367,744	9.56
Deep tube wells	159,725	4.17
Treadle pump (Dhiki)	79,145	2.06
Animal drawn cart	334,978	8.74
Other Equipments	290,084	7.57

Source : (CBS, 2013).

Drivers of Agricultural Mechanisation

Mechanisation in Nepal in the past is often influenced by not only as a result of government and donor support policies but also because of the long open border with India, where 4WTs and combined harvesters were being promoted as the symbol of a modern, commercial and efficient agriculture (Justice and Biggs, 2013). The major drivers of agricultural mechanisation in recent years are labour scarcity, high cost of production and increased focus on market oriented farming system including demographic shift and socioeconomic and policy changes in the country. It is triggered by easy availability and access of farm machinery in the market (low cost Chinese hand tractors, and pump sets, etc.) with commercialisation of agriculture and scarcity of labour for crop production and raising animals with rising animal fodder scarcity. In addition, liberal import policy for tractors and farm machinery and spill-over effect from neighbouring long-open border of India (Bihar, UP, WB) as a result of increasing emphasis on mechanisation in bordering regions of India have promoted use of farm machinery in bordering Terai and market accessible hills. Nepal's historical, cultural and even political connections along with a long and open border with India have led to different patterns for investments in agricultural mechanisation, whether it is farmers' buying machinery, establishing import and export businesses, or local manufacturing capability (Biggs and Justice, 2013).

Agricultural wage rate has more than doubled in less than one decade as a result of labour scarcity and increasing opportunity cost of labour in other sectors. This has stimulated the increasing use of agricultural machinery to substitute human and animal labour and reduce cost. Low tariff rate for the import of tractors and increasing access and availability of farm machinery in the market, such as 2WTs and 4WTs including enabling environment for the promotion of machinery and rural energy technologies in recent years has promoted mechanisation. This is evident by the most recent increasing use of combined harvesters for rice and wheat harvesting in Terai. Furthermore, recently some government R&D programmes are promoting agricultural machineries and technologies, such as zero and minimum tillage and other Resource Conservation Technologies (RCTs).

Policy Context on Agricultural and Rural Mechanisation

Mechanisation was often misunderstood in the past as use of large four-wheel tractors rather than encompassing whole sets of manually operated, animal drawn equipments and smaller machines (two-wheel tractors, pump sets, etc.). The past policies, such as Land Act (1964) focused on individual rights to land, land ceiling and land reform but not on commercial use of agriculture land and its productivity improvement. National Civil Code (1853;1962) also focused on land inheritance and individual rights to land rather than productivity improvement. Nepalese labour policy also has not adequately recognised the value of agricultural labour and its welfare aspects, such as drudgery reduction. Therefore, these policies mainly focused on individual property rights and equity which encouraged land fragmentation with the provisions of land inheritance and land ceiling resulting in disincentives for mechanisations. The major agricultural development policies and programmes formulated in the last decades, such as Agriculture Perspective Plan (1995-2015) and National Agricultural Policy (2004) also ignored mechanisation due to fear of labour displacement by the use of larger power operated machines (mainly tractor). The context of agrarian structure, (small farm size, fragmented land holding), geographical constraints of rugged topography and narrow terraces in Hills and Mountains and poor understanding of the role of rural and farm equipments other than large tractors also discouraged formulation of policies and programmes for adoption, use and promotion of machineries.

Recently, there is an increasing realisation of agricultural mechanisation among planners and policy makers in Nepal. With the economic liberalisation and need of agricultural development, government of Nepal since late 1990s opted liberal economic policies and encouraged import of agricultural machinery particularly tractors with the import tax exemption focusing on farmers. Most recently, Government of Nepal has formulated and approved "Agriculture Mechanisation Promotion Policy (2014)" to promote agricultural mechanisation and commercialisation in agriculture. Government of Nepal also has recently formulated Agriculture Development Strategy (ADS) which has also strongly recognised the need for promotion of agricultural mechanisation for the commercialisation and development of competitive agriculture. In addition, Government has very liberal import policies mainly tax exemption for the import of large agricultural machinery particularly tractors. There are many other cross-sectoral policies that have directly or indirectly influenced agricultural mechanisation in Nepal. The important ones are presented below;

Trade Policy

The Trade Policy (2010) is relatively favourable; it favours agricultural machinery with lower import to mechanisation duties (only 1% of import tax) and exemption of value added tax as compared to other machineries. However, the establishment of local agricultural machinery industries is difficult to flourish due to high import duty and value added tax on raw materials. This happens due to difficulty in separating agricultural raw materials with other agricultural machineries.

Energy Policy

Rural Energy Policy (2006) was favourable to mechanisation that uses rural renewable energy technologies. It has provision for providing 50-75% subsidy for the use of rural renewable technologies, such as solar dryer, solar pump, micro-hydro, cold storage facilities and machinery and equipments that are run by renewable and environment friendly energy including low tariff rate for irrigation.

Transport Policy

The existing Transport Policy (2002) is neutral to agricultural and rural mechanisation. There is no specific content and provision for promotion or restriction of the mechanisation. However, there is low renewal tax for agricultural machineries as compared to commercial vehicles, indicating that it is slightly fabourable to agricultural mechanisation.

Credit Policy

Credit sector has recently made priority on agricultural sector including mechanisation. Government of Nepal in the budget speech of 2014/15 made special credit interest rate subsidy to 6% from 10% of the current lending rate of commercial bank. The directive for the implementation of this interest rate subsidy scheme has been developed but most of the formal sector credit institutions (commercial banks) have not reached in rural areas. Moreover, the processing cost for credit is high and access is also not easy particularly for the use of farm machinery and equipments.

Industrial Policy

Industry Policy (2010) also makes emphasis on establishment of agrobased industries in addition to specific focus on overall industrial development. But due to high custom duty on raw materials and value added tax on it, there is little incentive for establishment of agricultural machinery based industries.

Subsidy Policy

The government of Nepal in fiscal year 2014/15 has allotted Nepalese Rs. 9.5 crores fund and initiated implementation of subsidy schemes to farmers for purchase of farm machinery. About 50% subsidy is provided to farmers who make purchase of specific farm machinery and equipments, such as power tillers with cultivators and mini-tillers. The focus of subsidy is on small-scale machinery and their attachments, but the amount of subsidy allocated is limited to promoting mechanisation to large number of farmers. Moreover, providing limited amount of flat subsidy on agricultural machinery may distort the market and under privileged groups of farmers will have difficulty in accessing government subsidy.

Impacts of Agricultural and Rural Mechanisation

In spite of the dominance of small and fragmented land holdings, physical constraints of rugged topography, lack of emphasis on past policy, agriculture mechanisation is spreading in many parts of Nepal including remote hills and mountains. Agricultural machinery is having a positive impact on smallholders since they are efficient in accomplishing timely farm operations, reducing cost and improving product quality. Small-scale threshers, pump sets, and tillage equipment are now more widely available, less expensive, and suitable for small-holders even in rural hills and mountains with increased road connectivity. Other farm machinery needed for harvesting and irrigation also have shown successful implementation in Terai. Use of farm machinery can reduce cost of production significantly since labour cost alone accounts for about 60-65% of the total cost of rice production in Nepal (Gauchan *et al.*, 2012). Field evidences from some parts of Terai and accessible central hills indicate that use of small-scale machinery has helped reduce women drudgery and improved efficiency in the production. Smallholders can also avoid capital investment as, increasingly, Nepalese machinery owners provide custom hiring of machines, particularly tillage equipments, threshers and combined harvesters (Biggs and Justice, 2013; Joshi *et al.*, 2012, Justice and Biggs, 2013). This trend of mechanisation has been growing over the past years as labour shortages arise. Evidence from Bangladesh indicates that the operation of the machines are highly profitable with higher income and profit from use of power tillers followed by that of power threshers and shallow tube wells, respectively (Hossain *et al.,* 2013). The cost of investment from machinery use is recovered within two years indicating farm mechanisation is an economically more preferred option as compared to conventional manually labour operated farming.

Role of Public and Private Sectors in Agricultural and Rural Mechanisation

Role of Public Sector in Agriculture and Rural Mechanisation

Recently, Ministry of ` (MoAD) has made efforts with private sector support in the formulation of Agricultural mechanisation Promotion Policy (2014), which is a good step in this direction. The state can speed up the process for implementation of Agro-mechanisation policy that has been approved by the Government of Nepal. The role of state is also to support long-term research and development programmes on agricultural mechanisation, which is participatory and client-oriented so that appropriate farmer-friendly tools, equipment, and machinery could be developed and promoted.

In areas where private sector has no incentives in provisioning services, public sector can take lead to facilitate implementation of mechanisation programmes, such as by linking with occupational caste of Nepal, who are engaged traditionally in rural area on manufacturing agricultural tools and equipments. This will help generate employment and poverty reduction in rural areas by engaging liberated bonded labour (*Haliyas),* particularly blacksmiths in manufacturing agricultural tools and equipment and helping to establish their cooperatives for the sale of such machinery.

Role of Private Sector Participation in Agriculture Mechanisation

Private sectors in Nepal have played an important role in the spread of agricultural and rural mechanisation. Potential exists for mechanisation, especially in powering the agriculture sector with tractors and other tillage equipment, and crop protection and harvesting machines. There are a number of private sectors run engineering workshops/metal craft workshops, mainly concentrated in the Terai; these are also involved in manufacturing as well as providing services for agricultural tools, equipment, and machinery. Some of them are providing critical services, such as repair and maintenance and custom hiring of machinery for small farmers who are not able to purchase machinery. Considering small farm size and hilly terrains, private sector investment is geared towards improvements in the two-wheel tractors. Private sectors can play important role in research on commercial viability and market research for agricultural machinery and equipments (Clarke, 2000). They will continue to play important role with better policy support and capacity building from public sector agencies. Private investment in small scale mechanisation can improve if the state provides an additional incentive in the machinery. At present, however, the machinery-supply industry is still dominated by few actors and is less competitive.

Issues and Concerns

Limited Availability and High Import Tax on Spare parts

Availability of spare part is a huge concern as Nepal imports its tractor, power tiller and other farm machinery and this is due to the weak financial status of both dealers and traders to stock necessary spare parts. A high cost of spare parts for agricultural machinery is the result of high import duty and value added tax (VAT). The heavy duty (15-45%) on importing raw materials for manufacturing has created a disincentive to all local engineering firms to engage in local production and sales of machinery, tools and equipment.

Subsistence Farming, Small and Fragmented Farm Size and Difficult Terrain

Nepalese farming system is mainly rainfed and subsistence oriented; two thirds of cultivated area suffers from inadequate availability of irrigation water. Subsistence farming, small farm size, fragmented land holding and physical constraints of rugged and steep topography and narrow terraces in hills and mountains discouraged use of machineries. Farm sizes are not only small but also fragmented into 3-4 parcels that are dispersed in different locations. Declining farm size with land fragmentation poses a significant challenge for agricultural mechanisation in Nepal. Smaller landholding size reduces the self-sufficiency of farms, and it also reduces incentive for farmers to invest in mechanised agriculture, farming infrastructure and tools due to weak economies of scale.

Technological Issues and Constraints

Farmers currently lack appropriate mechanisation technologies addressing the needs of diverse socioeconomic groups of farmers (women, small farmers), farming systems and agroecological domains. Technologies are needed for conservation farming, high value agriculture, value addition focusing on improved manual tools, animal drawn implements and appropriate mechanical machinery for tillage, intercultural operations, harvesting, post-harvest operations, transportation and processing. As the majority of farm operations are performed by women in rural areas of Nepal as a result of male migration, the tools and machinery currently promoted do not meet the specific needs of women farmers or reduce their drudgery.

Institutional Issues and Constraints

In Nepal, institutions for research, extension and educational programme in agricultural and rural mechanisation are very weak. Current R & D and educational institutions lack adequate resources, expertise and infrastructure facilities in agricultural engineering and technology on mechanisation. NARC Regional Agricultural Research Stations and major crop commodity programmes lack posts for agricultural engineering researchers (scientists) for farm power machinery research. Even though, Department of Agriculture (DoA) has nationwide network of agricultural extension programmes, the agricultural mechanisation related technologies are very limited due to a lack of approved posts of specialists in agricultural engineering. Major agricultural educational institutions, such as Agriculture and Forestry University and other agriculture related educational institutions also lack well established agricultural engineering and farm machinery disciplines.

Limited Access to Institutional Credit and Insurance Schemes

Farmers and agro-entrepreneurs currently face limited access to institutional credit, although interest rates of credit for tractors and other agriculture machineries are high. Farmers are mainly smallholders with limited cash to purchase and hire machinery. Agro-entrepreneurs also lack working capital. Furthermore, investment in farm machinery is highly risky due to various climate and market related risks in agriculture. Government of Nepal has recently initiated agricultural insurance programmes to reduce risk in farming. However, agricultural insurance schemes are not effectively implemented due to lack of adequate awareness among farmers, high transaction cost of administration and subsistence nature of farming in many parts of Nepal.

Limited Trained Human Resources

At present, the country lacks adequately skilled and experienced human resources in public and private sectors at all levels. The agricultural sector is less mechanised and commercialised because of the lack of skill related to manufacturing of farm machineries. Existing man power in public and private sectors are not only limited but they also lack adequate knowledge and skills in machinery manufacturing and servicing. Traditional artisans (blacksmiths) have been playing an important role in producing and repairing indigenous hand tools and bullocks drawn implements. They do however lack appropriate technical and capital support to develop their skill and volume of business.

Weak Agri-machinery Manufacturing Enterprises

Agri-machinery sub-sector in Nepal is emerging with dominance of small and medium sized enterprises. Currently, agri-machinery enterprises are mostly limited to repair and maintenance service sector and it lacks experience and technical knowledge related to business development services Their capacity to manufacture sophisticated agricultural machines and equipments is also very limited. The enterprises also lack information and adequate knowledge about production and marketing of quality machines and spare parts. Lack of quality control authority is also an issue for consideration.

High Prices and Uncertainty in the Availability of Rural Energy Sources

Farm mechanisation requires easy access to rural energy sources, such as electricity and petroleum products at affordable prices. But currently energy prices are very high and beyond the reach of small farmers due to lack of in-country production and stocking. Moreover, Nepal suffers from lack of adequate and uncertainty of access to energy sources (fuel, electricity) due to frequent load shedding and petroleum shortage for fueling power operated machines and manufacturing. Use of renewable energy for running and fueling machinery is very much limited.

Technological Options in Rural Mechanisation

Since late 1990s, some research centres in Nepal Agricultural Research Council (NARC) made efforts in technology development on agricultural mechanisation in collaboration with CGIAR centres. National Wheat Research Programme (NWRP), Agricultural Implements and Tools Research Centres (AIRC), Agricultural Engineering Division (AED) have been engaged in focusing development of conservation-agriculture (CA) technologies in collaboration with CGIAR centres mainly with CIMMYT. Recently the latest mechanisation technologies, such as Laser Land leveler (LLL); Direct-Seeded Rice (DSR); zero tillage on wheat, maize, and lentil crops; unpuddled transplanted rice (UTPR); and reduced tillage (RT) on wheat are being promoted by the collaborative research programmes. The Cereal Systems Initiative for South Asia (CSISA) project has also begun to validate and promote CA technologies again by providing a few units of various types of machines to groups of farmers in six selected districts of the Terai. CA-based technologies promoted by CSISA are considered to maintain soil health and are profitable as they reduce the cost of cultivation and enhance productivity. They also reduce drudgery, improve production efficiency and are sustainable and environmentally sound. Considering the diversity of agroecology, farming systems and socio-jeconomic context of Nepal, selective mechanisation using appropriate technologies and practices are suggested for specific context and conditions. Two major agricultural and rural mechanisation technologies that are developed and being promoted by NARC and other agencies in Nepal are outlined below.

Agricultural Production Technologies (Tillage and Intercultural Operation)

The agriculture production developed and tested in NARC include technologies for tillage, planting and intercultural operations (AED, 2013; NARC, 2012). These include, (i) mechanised rice transplanter, which is able to transplant rice in 0.20 ha/hour. It saves 50-60 human labour per ha. This facilitates machinery use in inter-culture operation as it is planted in rows; (ii) maize dibbler for planting maize in rows is being promoted, which is efficient as compared to traditional manual sowing using plough; (iv) minimum tillage by power-tiller drills is a promising technology that performs three operations simultaneously- soil tilling, seed sowing, and planking. It saves on cost and overcomes the problem of poor plant-stand that can result from poor tilth and manual broadcasting (Joshi *et al.,* 2012). Hence, they are gaining popularity among small and medium-farmers in western Terai. Minimum tillage is beneficial which produces higher yields as compared with typical yields based on farmers' practice (Manandhar *et al.,* 2009; Pariyar *et al.*, 2001). The technology on intercultural operation that is tested and promoted includes, (iii) mechanised intercultural operation for maize using tractor. It includes tractor fitted with 4/11 tyne cultivator which is very efficient and saves 80% of human labour. There are also different types of irrigation technologies, such as pump sets, drip and sprinkle, etc., which are being promoted both by private and public sector organisations.

Technologies for Postharvest and Processing

There are some indigenous and newly promoted postharvest and processing technologies available in Nepal in agriculture and rural development. These include NARC developed and recommended technologies, such as corn sheller, millet thresher, coffee pulper, ginger peeler, seed cleaner, solar dryer (AED, 2013; NARC, 2012). These technologies help reduce cost, improve efficiency, and minimise women drudgery. The capacity of corn sheller technology is 15 kg maize shelling per hour whereas a woman can shell manually only 5-8 kg per hour. Millet thresher cum pearler has a capacity of threshing and pearling 40-50 kg/hr of finger millet, which has been very useful to provide relief to women engaged in millet threshing. It is far better than conventional means as it has threshing efficiency of 97% and pearling efficiency of 98%.. The roller type coffee pulper has capacity of 60 kg/ hr, which has been transferred to private sector (more than 200 pulpers are commercialised). Solar dryer technology has been also developed and promoted to dry fresh and perishable products for value addition. This is appropriate to dry apple, vegetables, fish and meat at a temperature that ranges from 35to 55 degree Celsius.

Wheat thresher which was introduced from India in early 1970s is being popular in Nepal. Wheat threshing in Terai is fully mechanised with the use of thresher. It is estimated that over 100,000 wheat threshers are currently operating in Nepal. An important and popular technology being promoted through I/NGOs are biogas plants and solar dryers which have been energy efficient, climate smarts and spread widely. There are also some promising indigenous technologies which are being upgraded and promoted for processing, drying and cooking. These include rural water mills (*ghattas*), gravity rope ways, improved cooking stoves, etc.

Conclusions

Adoption and spread of agricultural and rural mechanisation technologies are increasing recently in Nepal with liberal import policies, increased connectivity and acute labour scarcity resulting from youth migration. Feminisation in agriculture is apparent. In addition, spill-over effect from India also played important role in the promotion of mechanisation in the bordering Terai districts. Agricultural machinery is having a positive impact on smallholders since they are efficient in accomplishing timely farm operations, reducing cost and improving product quality. With increased road connectivity, market accessibility and liberal economic policy, small-scale threshers, pump sets, and tillage equipments are now more widely available; these are less expensive, and suitable for small-holders even in rural hills and mountains. The country needs to identify, evaluate and promote widely promising existing indigenous and newly developed technologies on production, post-harvest and processing to spur agricultural growth in the country. Considering diversity of geography, agroecology, farming system and socioeconomic setting, selective mechanisation is suggested in Nepal based on specific context. Focus need to be given on custom hiring of machines with enabling policy environment and programme activities. Special efforts should be made in the development, testing and promotion of resource conserving, environmentally safe, women and youth friendly mechanisation technologies suited to small-scale farming of Nepal.

Recommendations

Focus on Small-scale Mechanisation

Considering a small farm size and fragmented land holdings and difficult terrain of hills and mountains, promotion of small-scale machinery is most suited for Nepal. This case is supported by the evidence of success of small scale farm mechanisation of neighbouring countries e.g., China and Bangladesh (see Mandal, 2014 for illustration of Bangladesh case). Therefore, there is a strong argument of policy intervention in favour of small-scale machinery to smallholder farmers (see Biggs *et al*., 2013 and Justice and Biggs, 2013). Small scale farm mechanisation focusing on women and youth friendly machineries is essential for enhancing access, improving production efficiency and addressing labour scarcity caused by youth migration and feminisation in agriculture (Gauchan, 2014). Promotion of small scale farm mechanisation is also best suited to the difficult topography of the hills and mountains of Nepal.

Custom Hiring of Farm Machineries

Considering the dominance of resource poor farm households and relatively large investment required for farm machinery at the individual household level, developing market for custom hiring will be best strategy to promote agricultural mechanisation in Nepal. This will require enabling policy and institutional environment that government of Nepal needs to promote and address. In such context, small-scale machinery is not always the best choice. Small scale machinery will be most suited to hills and mountains where terrains are difficult and plots are of smaller size and fragmented. In the flat land of Terai, where road connectivity exists and farm sizes are larger, relatively large size machinery (e.g. combine harvesters, and mobile threshers) will be the best technology and custom hiring of such expensive machinery will be viable economic option for the vast majority of farmers. In the past, custom hiring of large equipments was dominated by Indian machine owners but more recently, increasingly, Nepalese machine owners are being popular in custom hiring of equipments for tillage, harvesting and threshing. Therefore, there is a need to develop and implement an appropriate policy to facilitate custom hiring for the wider benefit of smallholders. Research on the evaluation of performance of models of custom hiring services provision will be essential to design and recommend appropriate custom hiring options.

Cooperative Farming, Contract Farming, Land Banking and Land Consolidation

Considering a small and fragmented landholdings, use of machinery through the promotion of rural institutions, such as cooperative farming and community based organisations (CBOs) would be most suited in Nepal. This will provide economic use of tractors and other machineries when large number of farmers is organised into cooperatives for collective use to improve efficiency and reduce cost of production. In addition, for economic use of farm machinery, there is a need of regulation of land registration to encourage farmers' of larger land holding size. Furthermore, legislation on land leasing, contract farming and land banking are suggested options for promoting mechanisation and commercialisation of agriculture. Land consolidation is the obvious antidote to high levels of fragmentation. Consolidating a land owner's holding into a single location is by no means a simple task but it can be achieved by sale and purchase and through mutual exchange employing concept of land banking. Land consolidation has been successfully achieved elsewhere, most notably in Taiwan where agricultural productivity has increased by 32% (ADS, 2014).

Institutional and Human Resource Development in Agriculture and Rural Mechanisation

In order to promote farm mechanisation, there is a need to develop and strengthen institutional and human resource development in farm mechanisation at all levels (national, sub-national & local level) and ecological and development regions. This will require strengthening existing Agriculture Implement Research Centre (AIRC), Birganj and Agri Engineering Division (AED), NARC and establishment of new research centres in hills, mountains and mid/far western Terai region. Similarly establishment of agricultural engineering /farm mechanisation units in each of district agricultural development offices with adequate trained professional is needed for promotion of mechanisation extension programmes. Agricultural educational institutions also need to be strengthened for agricultural and rural mechanisation faculties and course curricula. Private sector manufacturing establishment and repair and maintenance workshops in different regions and locations are to be promoted and supported with suitable policies and programme. In addition, capacity building of indigenous entrepreneurs (e.g. blacksmiths) and agro-related metal working industries is essential for in-country production of farm machinery prototypes that are adapted to fragmented lands and small holdings. Research capability in agricultural mechanisation needs to be strengthened.

Development and Promotion of Safe and Environment Friendly Mechanisation Technologies

Development of technologies on conservation farming with suitable accessories to farm machineries and attachments (e.g., planters, zero till drill, hoes, etc.) will help to improve efficiency in cultivation, conserve resources (water, energy) and reduce cost and labour demand. In addition, this will promote commercialisation of agriculture related to postharvest handling, storage and distribution of products. Other interesting areas of R&D are enhancing machine use efficiency, safety (both operators' safety and environmental safety), quality standards; and the prospects of using renewable energy like solar pumps, solar dryers, bio-fuel, biogas plants etc in operating farm machines. Research on development and piloting of advanced technologies, such as precision farming technologies is suggested to accomplish agricultural operations timely with the highest efficiency, thereby the quality of agricultural products specified by their ingredients, freshness, maturity and shelf life are improved, leading to higher prices at the market.

Targeted Policy Interventions with Portfolio of Incentives and Support Measures

The government needs to make provisions for appropriate policies and regulations on mechanisation, preferential treatment on capital machinery importation and multiple value added tax on imported raw materials. Tax and subsidy rationalisation is needed to promote use of farm machinery without distorting market and making compatible with private traders' incentives. Considering the need to focus on small-scale environmentally safe farm mechanisation, differentiated and targeted import duty is needed for raw materials, spare parts, machineries, accessories and attachments. Financing and credit policy with soft and easy loans for agricultural machineries and commercial agriculture in rural areas is suggested. Implementation of insurance schemes to minimise risks in farming is essential for the adoption of farm mechanisation and commercialisation of agriculture. This will require a portfolio of policy incentives and support measures for farmers and stakeholders to modernise and commercialise agriculture through enhancing adoption of appropriate agriculture and rural mechanisation technologies. An immediate work plan is needed for the development of strategy and action plans for the implementation of new Agriculture Mechanisation Promotion Policy that includes most of these suggested policy options including formulation and implementation of other policies, legislations and regulations favouring commercialisation of agriculture. (e.g. Contract Farming Act, Land leasing legislation, Agriculture Land Use Act, Cooperative Act, etc.).

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Chapter 5

Patterns of Farm Mechanisation in Bangladesh

Akhter U. Ahmed

Introduction

Farm mechanisation is the process of developing agricultural machines and substituting this machine power for human and animal power in agricultural production. Mechanised agriculture greatly improves agricultural production efficiency and increases farm worker productivity. On the other hand, it displaces unskilled farm labour and may cause environmental pollution.

Following the devastating cyclones in the 1980s that killed many draft animals in Bangladesh, government policies promoted the wide-scale use of Chinese-made two-wheel tractors or power tillers (Biggs *et al.*, 2011). The cropping intensity and production of food crops have increased significantly in Bangladesh due to the adoption of mechanised tillage, irrigation, and spraying operations (Sarker, 2000).

In Bangladesh, farm machinery includes machines driven by diesel engines or electrical motors and manually-operated modern farm implements. Engine- or motor-driven equipment includes shallow tube wells, deep tube wells, and low-lift pumps for irrigation; two-wheel power tillers and four-wheel tractors for land preparation; and combine harvesters and reapers for harvesting. Manually operated modern farm implements include pedal threshers, pesticide and weedicide sprayers, briquette (*guti*) urea fertiliser applicators, seed drillers, weeders, and so on. Although mechanisation has increased rapidly, most machines use concentrates on irrigation and land preparation (ploughing) services.

This chapter explores the extent of farm mechanisation in Bangladesh and its patterns using data from a nationally-representative rural household survey. The paper is organised in four sections. Section 2 describes the data used for this study. Section 3 presents the results, while Section 4 provides policy conclusions.

Data

The data for this study came from the Bangladesh Integrated Household Survey (BIHS), which has been conducted by the International Food Policy Research Institute (IFPRI) under the Bangladesh Policy Research and Strategy Support Programme (PRSSP) funded by the U.S. Agency for International Development (USAID). BIHS has been approved and facilitated by the Ministry of Agriculture and the Ministry of Food, Government of the People's Republic of Bangladesh (Ahmed *et al.,* 2013).

BIHS is the most comprehensive, nationally representative household survey conducted in Bangladesh to date. Varied studies can and do make use of the survey's integrated data platform to carry out research with policy implications for the country's food security and agricultural development. Moreover, the survey has been designed to provide the baseline data for the USAID-supported Feed the Future (FTF) zone in southern Bangladesh.

The BIHS sample is statistically representative at the following levels: (a) nationally representative of rural Bangladesh; (b) representative of rural areas of each of the seven administrative divisions of the country: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, and Sylhet; and (c) representative of the FTF zone.

A sound and appropriate statistical method was used to calculate the total BIHS sample size of 6,500 households in 325 primary sampling units (PSUs). The sample design of the BIHS followed a stratified sampling in two stages: selection of PSUs and selection of households within each PSU using the sampling frame developed from the community series of the 2001 population census of Bangladesh. Later, sampling weights were adjusted on the basis of the latest population census of 2011. The domain of the national survey was the rural areas of the entire country.

For implementing the BIHS, IFPRI contracted Data Analysis and Technical Assistance (DATA), a Bangladeshi consulting firm with expertise in conducting complex surveys and data analysis.

DATA worked under the supervision and guidance of senior IFPRI researchers. DATA's capacity to conduct surveys with high-quality data was largely built by IFPRI over the past two decades.

The survey started in October 2011 and ended in March 2012. After data entry and cleaning, DATA delivered the complete dataset to IFPRI by the end of June 2012. The BIHS is planned to be repeated to create a 3-round panel survey: the second round was conducted in 2015 and the third will be conducted in 2018. The 2011-2012 BIHS dataset is available online at the following IFPRI and USAID/Feed the Future websites:

http://www.ifpri.org/dataset/bangladesh-integrated-household-survey-bihs-2011-2012

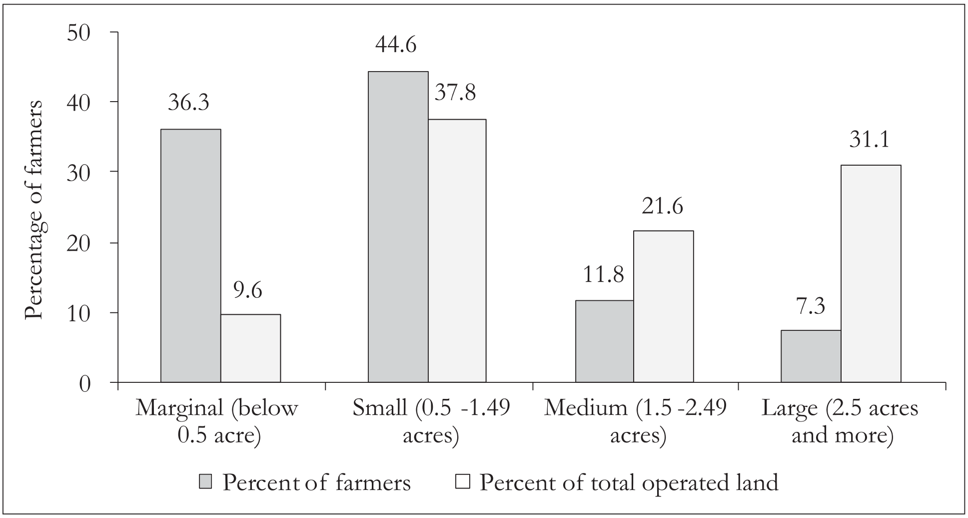
http://www.agrilinks.org/library/feed-future-bangladesh-integrated-household-survey-dataset

Results

This section presents the extent of farm mechanisation in Bangladesh using data from the 2011-2012 BIHS baseline survey. Much of the farmers level analysis in this study disaggregates the sample farmers into four operated farm size groups: (1) marginal (< 0.5 acres); (2) small (0.5-1.49 acres); (3) medium (1.5-2.49 acres); and (4) large (≥2.5 acres).

The four farm size groups match the cut-off points of the six operated farm size groups in the 2010 Household Income and Expenditure Survey (HIES) report of the Bangladesh Bureau of Statistics (BBS, 2011). It aggregates the smallest two HIES farm size groups under the marginal farm category and the largest two groups under the large farm category.

Figure 1
Distribution of Operated Land by Farm Size Groups in Rural Bangladesh



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

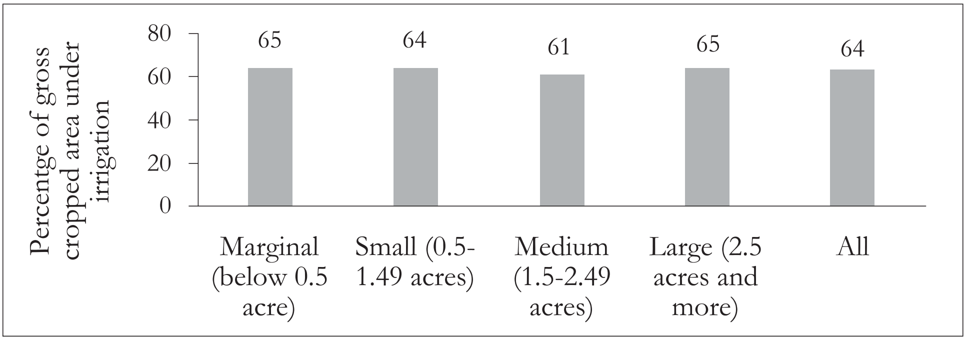
Figure 1 shows the distribution of operated land by farm size groups in rural Bangladesh. More than one-third (36 percent) of all farmers are marginal farmers who operate only about 10 percent of total operated land in the country. At the other extreme, only about 7 percent of all farmers are large farmers who operate about 31 percent of total operated land.

Mechanised Irrigation

Irrigation is one of the most critical factors of agricultural production in Bangladesh. Since the early 1970s, rice production tripled, which was largely due to irrigation. Irrigation increases food grain production in Bangladesh because (1) it enables farmers to grow an additional *boro* rice or wheat crop during the dry winter season, and thus increases cropping intensity and eases the land constraint; (2) when complemented with fertilisers and modern high-yielding rice varieties, it significantly raises rice yields in comparison to rain-fed rice cultivation; and (3) supplemental irrigation can take much of the risk out of the two predominantly rain-fed rice seasons- *aus* and *aman* (Ahmed and Sampath, 1992).

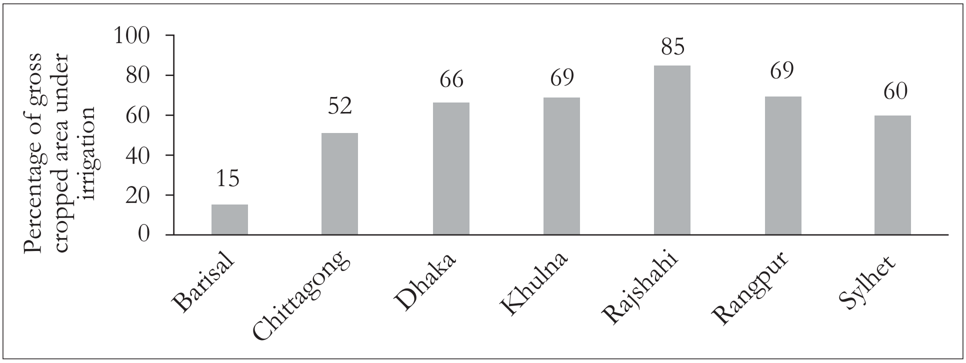
BIHS data suggest that about 64 percent of gross cropped areas in rural Bangladesh are irrigated. There is no noticeable pattern between irrigation coverage of cropped areas and farm s/ e (Figure 2). Regionally, irrigation coverage ranges from only about 15 percent of total cropped land in Barisal division to about 85 percent in Rajshahi division (Figure 3).

Figure 2
Percentage of Gross Cropped Area Irrigated by Farm Size Groups in Rural Bangladesh



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

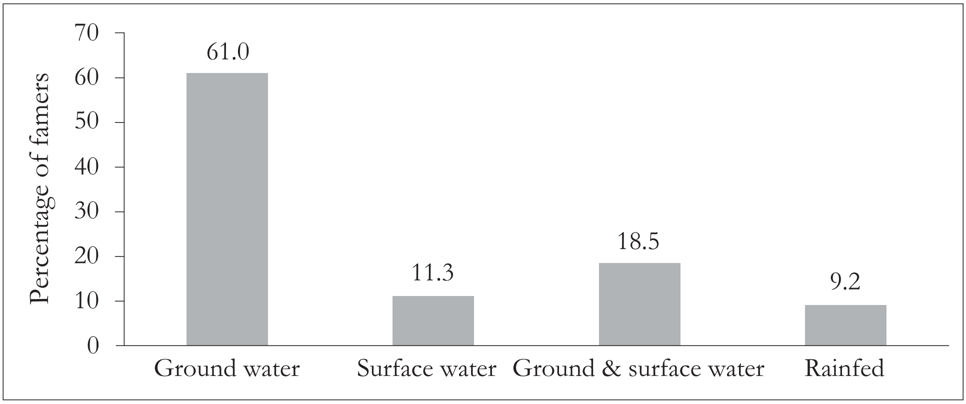
Figure 3
Percentage of Gross Cropped Area Irrigated by Division



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Groundwater is the main irrigation source in rural Bangladesh, which is used by 61 percent of farmers. Approximately 11 percent of farmers use surface water irrigation, while 18.5 percent of farmers use both irrigation method (Figure 4). Nine percent of farmers grow crops without irrigation and rely on rainfall; however, this proportion varies widely by division (1 percent in Rajshahi division versus 65 percent in Barisal division). Further, farmers in Barisal utilise almost exclusively surface water irrigation, accounting for 34.9 percent of farmers (Table 1).

Figure 4
Source of Irrigation



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

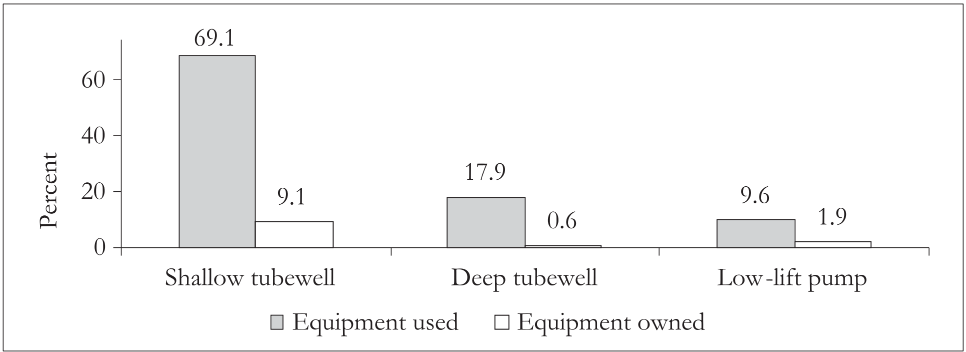
Bangladeshi farmers use traditional and modern irrigation methods. Traditional methods include dhoone (a water-lifting device), swing basket, and dug-well, and modern techniques include shallow tube wells (STWs), deep tube wells (DTWs), low-lift pumps (LLPs), hand pumps, and sophisticated canal gravity-flow irrigation schemes. Among these, dhoone, swing basket, and LLP use surface water, while dug-well, STW, DTW, and hand pump rely on groundwater irrigation.

Table 1
Irrigation Source by Division in Rural Bangladesh

Source of Irrigation	**Division**							
	Barisal	**Chittagong**	**Dhaka**	**Khulna**	**Rajshahi**	**Rangpur**	**Sylhet**	**Bangladesh**
(percent of farmers)								
Rainfed	64.6	17.4	5.1	10.7	1.0	4.5	14.7	9.2
Groundwater	0.5	34.7	67.4	58.9	71.8	81.3	16.8	61.0
Surface water	34.9	37.8	9.1	8.1	2.4	1.1	50.8	11.3
Groundwater & surface water	0	10.1	18.4	22.4	24.8	13.1	17.7	18.5

Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Figure 5
Use and Ownership of Mechanical Irrigation Equipment for *Boro* Rice Cultivation



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

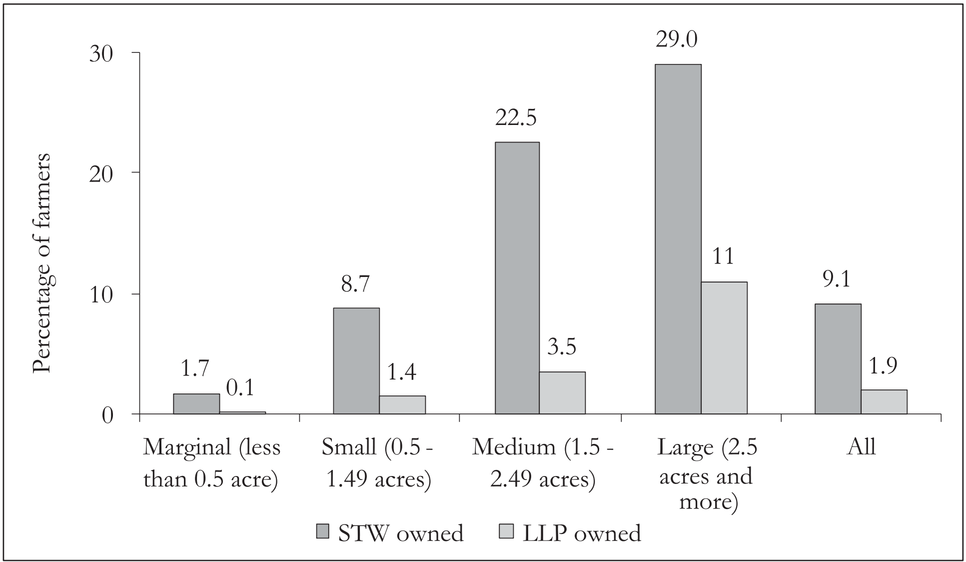
About 69 percent of farmers use STWs to irrigate *boro* rice in the dry season (Figure 5). DTWs are the second most prevalent method used by18 percent of farmers. The rate of irrigation equipment use is much higher than the rate of ownership, indicating a widespread rental market for irrigation services, particularly for STW irrigation.

Table 2
Irrigation Methods for HYV/Hybrid *Boro* Rice Cultivation by Division in Rural Bangladesh

Irrigation Method	Division							
	Barisal	**Chittagong**	**Dhaka**	**Khulna**	**Rajshahi**	**Rangpur**	**Sylhet**	**Bangladesh**
(percent of farmers)								
Manual	1.5	4.4	2.3	6.9	1.3	0.8	14.4	3.0
Shallow tubewell	2.9	50.6	76.3	79.7	58.6	90.5	35.4	69.1
Deep tubewell	0	4.4	14.0	5.9	40.1	5.3	0.7	17.9
Low lift pump	95.6	40.0	7.0	6.7	0.1	2.5	48.6	9.6
Canal irrigation	0	0.7	0.5	0.8	0	0.8	0.9	0.5

Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Figure 6
Ownership of STW and LLP by Farm Size Group



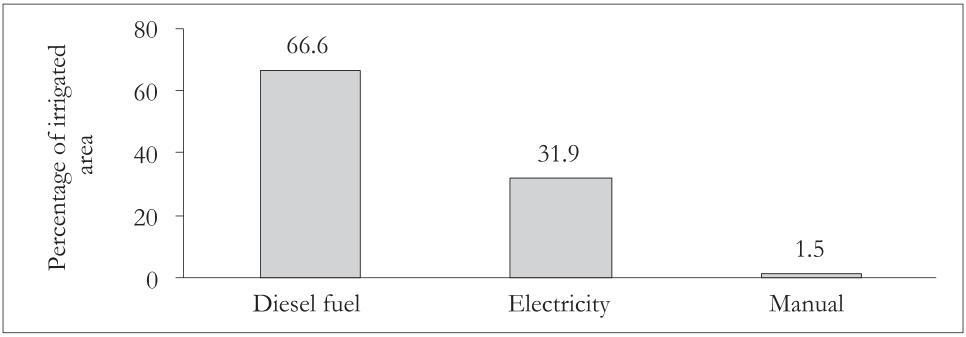
Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

However, irrigation methods vary extensively by division. In Barisal division, for example, only 3 percent of farmers use STWs to irrigate *boro* rice, and about 96 percent use LLPs. In contrast, there is negligible use of LLPs in Rajshahi division (only about 1 percent); instead, STWs (58 percent) and DTWs (40 percent) are the predominant irrigation methods for HYV/hybrid *boro* rice cultivation (Table 2).

Figure 6 shows ownership patterns of STWs and LLPs by farm size group. Ownership increases with farm size for both STWs and LLPs, but the magnitude of increase is much greater for STWs.

There are three primary forms of energy used for irrigation: (1) diesel fuel, (2) electricity, and (3) manual (Figure 7). Farmers use diesel fuel for approximately 67 percent of total irrigated area, and electricity to operate their irrigation equipment for about 32 percent of total irrigated area. Manual energy is mainly for traditional irrigation methods, such as dhoone, swing baskets, and dug-wells (1.5 percent).

Figure 7
Energy Used for Irrigation



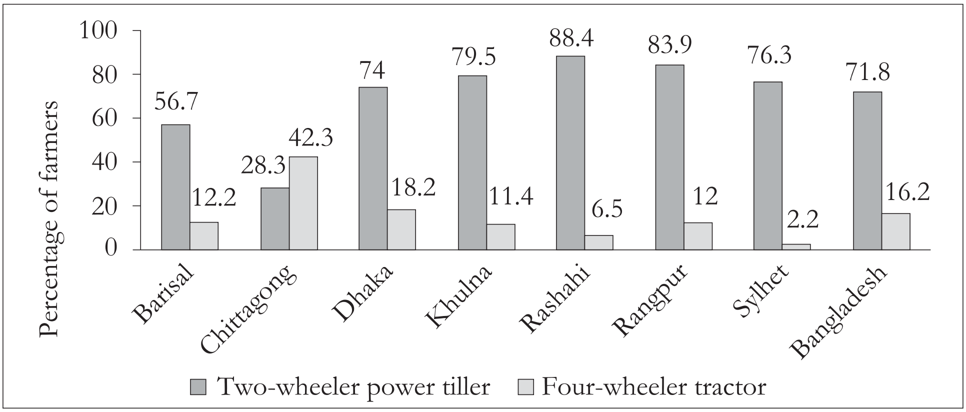
Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Use of Mechanical Power for Land Preparation

Mechanical power use for farmland preparation is quite high i.e., 72 percent of farmers at the national rural level use two-wheel power tillers (Figure 8). This is largely consistent across all divisions except Barisal and Chittagong divisions, which have 57 and 28 percent of farmers using two-wheel power tillers for land preparation, respectively. In contrast, four-wheel tractor use is significantly lower than two-wheel power tillers in all divisions except Chittagong in which the inverse is true.

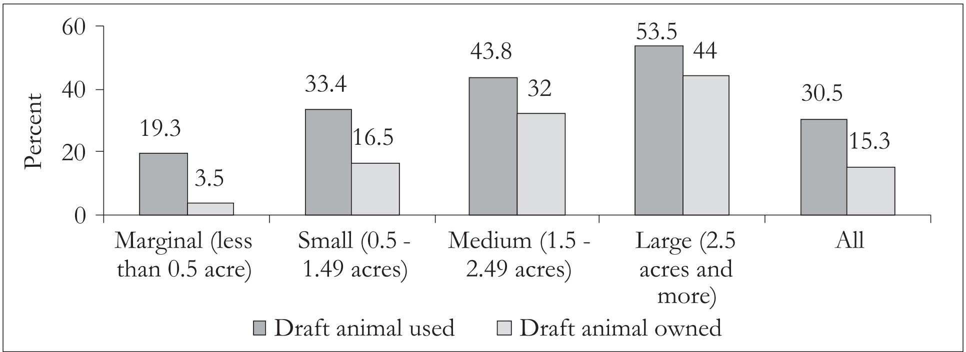
While mechanisation is gaining steam in Bangladesh, farmers continue to at least partially rely on animal power in agricultural production. Almost one-third of farmers nationally still use draft animals for land preparation, mainly for land leveling after machine ploughing (Figure 9). As farm size increases, the use of draft animals for land preparation likewise increases. Further analysis illuminates regional disparities in draft animal use, which ranges from 16 percent of Chittagong division, the lowest in the country, to 44 percent of farmers in Khulna division farmers (Figure 10).

Figure 8
Farmers Using Machines for Land Preparation



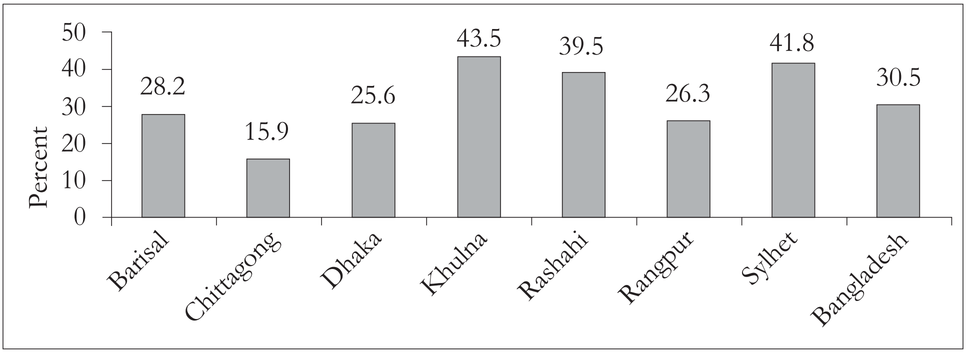
Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Figure 9
Draft Animal Use for Land Preparation by Farm Size Group



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

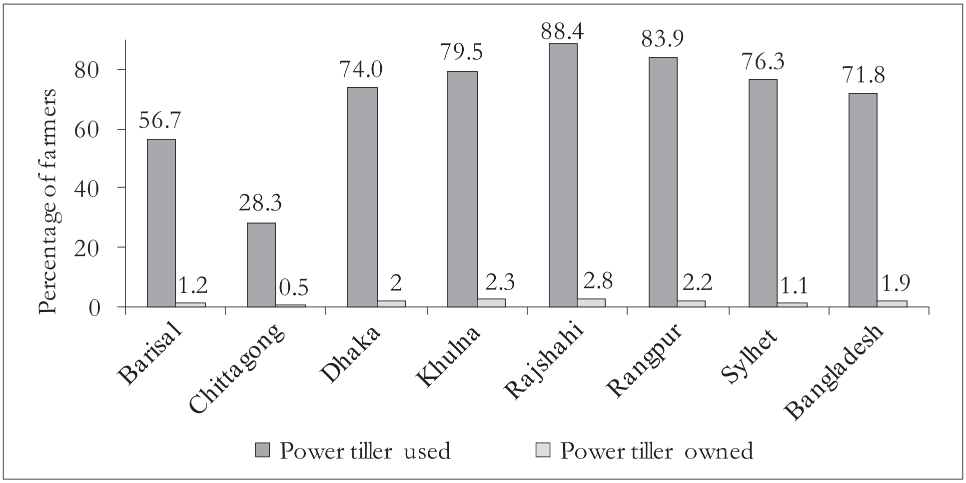
Figure 10
Draft Animal Use for Land Preparation by Division



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Division-wise distribution of two-wheel power tiller usage by farmers is quite skewed (Figure 11). Chittagong Division reports only 28 percent usage, compared to more than 50 percent in all other divisions, with the highest incidence in Rajshahi Division (88 percent). Although Chittagong Division reported low two-wheel power tiller usage, it boasts the highest division-wise four-wheel tractor usage at 42 percent, while the rate is less than 20 percent in the remaining six divisions (Figure 12).

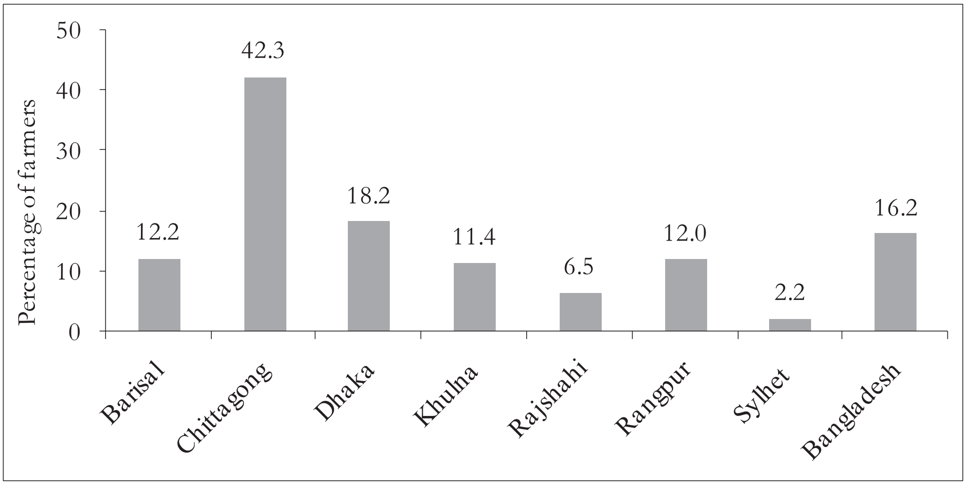
Figure 11
Two-wheel Power Tiller Use by Division



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Two-wheel power tillers have a relatively high uptake among farmers compared to other agricultural machineries, which holds true for all farm size groups (Figure 13). There are nominal variations in power tiller use between small (79 percent), medium (84 percent), and large farms (85 percent). Still, over half of marginal farmers (58 percent) use power tillers. Consistent with other agricultural machineries, power tillers are seldom owned. Only 10 percent of large-size farmers own power tillers, with an overall national average of 1.9 percent. This further underscores the thriving rental markets for agricultural machineries in the country.

Figure 12
Four-wheel Tractor Use by Division



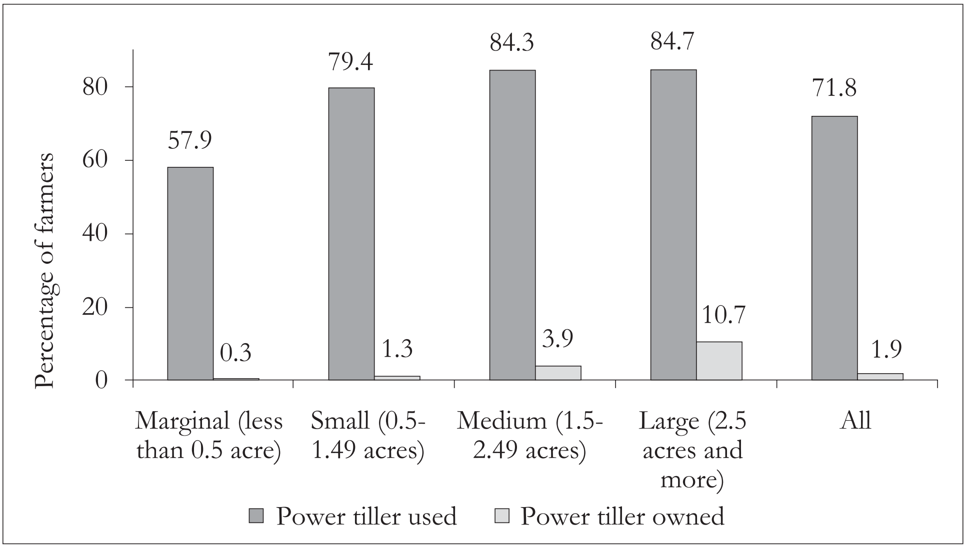
Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Four-wheel tractor use is relatively consistent across all farm size groups (Figure 14). Interestingly, 17 percent of small farmers use tractors, more than any other farm size group.

Tractor ownership is nearly non-existent across all farm size groups, with ownership peaking for medium farmers at 0.5 percent. Extremely low rates of tractor ownership as compared to use by 16 percent of farmers nationally reinforce the flourishing agricultural machinery rental market.

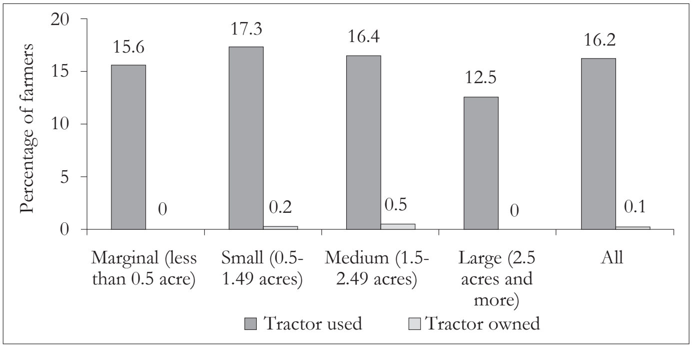
Figure 15 demonstrates farm size groups that use and own pesticide sprayers. About one-quarter of all farmers in Bangladesh use mechanical sprayers. More farmers use agricultural inputs like pesticide sprayer than own, which is consistent across all farm size groups. This further reinforces the presence of rental service market even for small agricultural equipment like pesticide sprayers. Usually, these small cheaper machines are owned by relatively poor households who provide the pesticide spraying services for fee per unit of crop land sprayed. As expected, as farm size increases, the percent of pesticide sprayer used and owned increases.

Figure 13
Power Tiller Use and Ownership by Farm Size Group



Source : IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Figure 14
Tractor Use and Ownership by Farm Size Group



Source: IFPRI Bangladesh Integrated Household Survey, 2011-2012.

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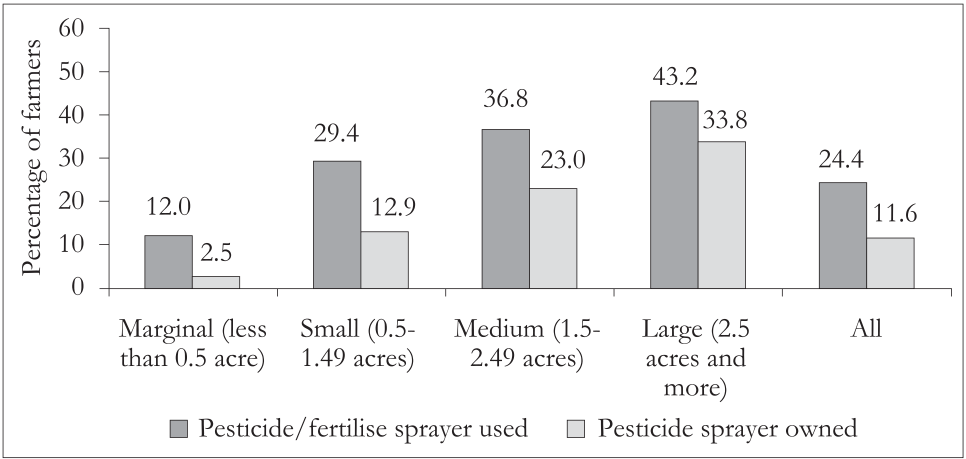
Figure 15
Pesticide Sprayer Use and Ownership by Farm Size Group



Source: IFPRI Bangladesh Integrated Household Survey, 2011-2012.

Conclusions for Policy

Growth in farm mechanisation in Bangladesh was mainly generated by (1) enabling policy reforms, and (2) labour market competition caused by the growing manufacturing and service sectors. Rural labour became scarce as more workers shifted to the formal sector and other non-farm jobs, bidding up rural real wages and thereby enhancing total labour earnings. Since physical labour is the poor's most important asset, escalation of real wages boosted earnings, improved food security and livelihoods, and helped the poor escape poverty.

Rapid farm mechanisation and agriculture commercialisation have created (1) substantial employment opportunities for repair and servicing, and (2) a thriving agricultural machinery rental market. Farmers across all regions and farm sizes use agricultural machineries, yet only a small fraction owns these machineries. Thus, the emergence of a farm machinery rental market with broad participation posits significant opportunities for the Government of Bangladesh to collaborate with private sector partners to accelerate agricultural development, particularly in the wake of rising labour costs.

Farm mechanisation has increased dramatically in Bangladesh; however, it has concentrated on ploughing and irrigation. Two-wheel power tiller operated and four-wheel tractors are used mainly for poughing in Bangladesh, with about one-third of farmers still using animal power (bullocks) for land levelling after ploughing by tractors. Land levelling and other tools attached to two-wheel power tillers have great potential to replace draft animals for land preparation, and thereby increase agricultural production efficiency.

Indeed, Bangladeshi manufacturers have already started producing and selling various farm machineries as attachments to two-wheel power tillers (Krupnik *et al*., 2013). These attachment machineries are compatible with conservation agriculture practices, which entail reduced tillage, retention of crop residues on the soil surface, and use of crop rotations to build soil quality, conserve agricultural resources, and reduce production costs (Roy *et al.,* 2009).

In this regard, recent efforts, such as the Cereal Systems Initiative in South Asia – mechanisation and Irrigation (CSISA-MI) Project hold promise. CSISA-MI promotes up- and downstream market interventions to ensure machineries needed for agricultural intensification. These are sustainably available through local markets. Key government partners of this initiative include the Bangladesh Agricultural Research Council (BARC), the Bangladesh Agricultural Development Corporation (BADC), and the Department of Agricultural Extension (DAE). CSISA-MI is primarily funded by USAID under its Feed the Future (FTF) Initiative, and the European Union and the Australian Government also grant funding.

The expansion of promising initiatives, such as CSISA-MI throughout the country may smooth out regional disparities in farm mechanisation, increase smallholder farmers' access to machineries to boost production, and thereby contribute to a sustained increase in farmers' productivity and incomes.

Rural agricultural labour is no longer abundant in Bangladesh; thus, policies should focus on how to improve productivity in view of rising labour costs. Rapid farm mechanisation, together with accelerated adoption of modern agricultural technologies for improving crop yields, may ease this burden.

Acknowledgements

We gratefully acknowledge the United States Agency for International Development (USAID) for funding the Policy Research and Strategy Support Programme (PRSSP) in Bangladesh under USAID Grant Number EEM-G-00-04-00013-00. This paper is an output of the PRSSP.

The study would not have been possible without the dedication and hard work of the survey enumerators and other staff of the Data Analysis and Technical Assistance Limited (DATA), a Bangladeshi consulting firm that carried out the 2011-2012 Bangladesh Integrated Household Survey (BIHS) under the International Food Policy Research Institute (IFPRI)'s supervision. Data for this report came from the BIHS. We are particularly grateful to Zahidul Hassan, Managing Director of DATA, for his overall support.

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Chapter 6

Nature and Impact of Agricultural Mechanisation in Bangladesh

Mahabub Hossain, A. N. M. Mahfuzur Rahman, and Sudhir. C. Nath

Introduction

The productivity growth in agriculture originated from two types of technological progress. First is the bio-chemical technology that increased land productivity through development and diffusion of improved varieties and associated use of irrigation and chemical fertilisers, which is appropriate for land-scarce situations. The other is the mechanical technology that substitutes labour for capital and increases labour productivity which is appropriate for labour-scarce situations. Bangladesh including many other land-scarce counties in Asia invested heavily in the Research and Development (R&D) system for development of improved crop varieties, and provided policy support for provision of irrigation facilities, supply of agricultural credit at affordable interest rates, and subsidies for chemical fertilisers to promote faster adoption of the technologies by the farmers in order to increase the land productivity. The development and diffusion of mechanical technologies followed later when a) labour and animal draft power became scarce with the absorption of labour in the fast growing manufacturing and services sectors, and b) maintaining draft animals to provide draft power to agricultural activities became costly due to growing shortage of animal feeds and the opportunity cost of labour for maintaining the stock of animals.

Bangladesh has achieved respectable growth in land productivity and in agricultural production through continuous development of improved varieties of rice, wheat, maize, potatoes, and vegetables (Hossain, 2012). Although the land frontier was exhausted in the 1960s, and the cultivated land started declining with increase in demand for land for housing, industrialisation and infrastructure development, the growth in agricultural production accelerated since late 1980s. The agricultural research institutes allocated small amount of resources for adaptation of mechanical technologies imported from abroad, but there was little attempt to commercialise them through partnership with the private sector for large-scale manufacturing, and sales to farmers. The use of these technologies by farmers is a recent phenomenon, and many of the machines are imported from other countries.

This chapter provides an overview of government policies for promoting agricultural mechanisation in Bangladesh. It also depicts the picture of the characteristics of agricultural mechanisation and its effect through generation of primary data through farm household and machine owners' survey. Section 2 provides an overview of government policies and the factors behind the adoption of mechanical technologies. The methodology of generation of primary data is explained in Section 3. The characterisation of prevailing mechanisation as found through the surveys is presented in Section 4. Section 5 presents the findings of the surveys on the effect of mechanisation. The main findings are recapitulated in Section 6.

Drivers of Agricultural Mechanisation

An Overview of Government Policies

Mechanisation in Bangladesh was promoted in the 1960s with the introduction of tractor, low-lift pumps, and deep tube wells, albeit on a limited scale. These equipments were supplied mostly by Bangladesh Agricultural Development Corporation (BADC), Water Development Board (BWDB), and the Bangladesh Academy for Rural Development (BARD). The objective was to raise labour productivity through reaping economies of scale. The large scale machinery was, however, found "inappropriate" in the context of small and marginal farms dominated agrarian structure in Bangladesh. The BARD and BADC had limited success in reaching farmers with the machines except small scale power pumps for lifting surface water for irrigation (Bose, 1974).

The First Five Year Plan of Bangladesh continued a positive policy on promotion of tractors under the umbrella of farmers' cooperatives, termed as "Cooperative Capitalism". Many tractors were imported in the early 1970s, and were fielded through the cooperatives, but their use for tillage remained limited. Some of the tractors were later used for transportation of harvest and hauling other agricultural products. Social scientists were against promoting agricultural mechanisation because of the perception of negative effects on employment of the landless that contribute to worsening distribution of rural incomes.

Faced with criticisms of premature mechanisation and inappropriate technology, the government in late 1970s promoted the adoption of minor irrigation equipment- shallow tube wells, and power pumps, and small capacity deep tube wells- initially through subsidised investment financing from financial institutions, and later adoption of a policy of liberalisation of imports and reduction in import duties for diesel engines and agricultural machinery. The government also adopted a programme of disinvestment of the government owned power pumps and shallow tube wells in favour of farmers' cooperatives.

Although the policy of liberalisation was introduced in 1979, the process of implementation was slow due to (a) the reluctance on the part of the civil servants to release control and power, and (b) a limited private market for repair and maintenance of the equipments (Mandal, 1987, 1989, 1993). Throughout the 1980s, there were continued efforts to decrease public sector involvement in procurement and marketing of shallow tube wells and the momentum grew for the private sector investment (Palmer Jones, 2002; Ahmed, 1995; *et al.*, 2000). Nonetheless, BADC continued to subsidise spare parts and repairs, which created a disincentive to the development of local repair and maintenance facilities (Mandal, 1989).

Policy reforms advanced, however, in 1988 when leadership in agricultural ministry changed. The then Secretary, Ministry of Agriculture took a direct interest in implementing the liberalisation programme for agricultural machinery and equipment. He visited the diesel engine markets in Dhaka, asked traders of the obstacles they faced, directed policy changes to remove the constraints, and ensured that the changes were approved by the government (Hossain, 2010). In 1988, the government eliminated duties on import of diesel engines, withdrew standardisation requirements for the import of machines, and allowed imports of agricultural machinery without government permits. The import duties were re-imposed in the 1990s, but the rates were much lower than those prevailing in mid-1980s. In recent years, the government has started providing subsidies on agricultural machines to the extent of 25 to 60 percent depending on the type of machinery.

Factors Behind Adoption of Farm Mechanisation

As mentioned earlier, few farmers went for adoption of mechanised cultivation in the 1960s and 1970s. But mechanisation spread very fast since

1988 (Table 1). The key factor was positive government policy introduced in late 1980s to promote mechanisation through the private sector. These policies contributed to reduction in the cost of machine, and development of a market for renting services of the equipment. Many educated unemployed youth started investing in the machines to run a business of machinery services, and provided access to these services to marginal and small farmers. Over time the competition in the market led to reduction in rental charges that provided incentives to farmers to go for mechanised farming.

Table 1
Growth in Agricultural Machinery under Operation, 1977-2012

Type of Machines	**Number of Machines (in thousand)**					
	1977	**1984**	**1989**	**1996**	**2006**	**2012**
Tractors	0.3	0.4	1.0	2.0	12.5	40.0
Power tillers	0.2	0.5	5.0	100	300	700
Power thresher	nil	0.6	4.0	15.0	175	350
Deep tube well	4.5	15.5	22.5	24.5	28.3	33.7
Shallow tube well	3.0	67.1	224	325	1,182	1,549
Low lift pumps	28.4	43.7	57.2	41.8	119	140

Source : Roy and Singh, 2008; Mandal, 2014; Wohab 2010.

The second factor is to escape from the extreme drudgery in manual agricultural works. Workers have to labour in puddling paddy fields often under high sun and heavy rainfall. The manual irrigation method (using swing baskets and *dhoones*) for lifting surface water to the field from nearby low-lying lands with accumulated surface water from rainfall was highly labour-intensive and involved drudgery. When the farmer was in a situation of poverty, they had no choice but to provide labour in such inhuman working conditions. But with growing economic prosperity and the opportunity cost of labour, farmers went for renting agriculture machinery to enjoy leisure and comfort with the development of the market for machinery services.

Third, with growing scarcity of fodder, maintenance of farm animals for providing draft power became costly. This development promoted mechanisation of tillage operations and reduced dependence on animals for providing draft power. The ownership of cattle in large and medium farmers started declining although many of them continue to raise animals for the supply of milk and meat. However, the landless and marginal farmers started investment in cattle in the homestead with easy access to credit from the expanding market of loans from the microfinance organisations. As Table 2 shows, 55 percent of households owned cattle in 2008 compared to 67 percent in 1983-84, and the number of cattle per household also declined during the same period of time. It resulted in rising cost of hiring draft animals.

Table 2
Changes in Cattle Holding by Farm Size, 1983-84 and 2008

Farm Size	**Farms Holding Cattle (%)**		**No of Cattle Per Household**	
(acres)	**1983 - 84**	**2008**	**1983 - 84**	**2008**
Up to 0.49	30	37	1.88	1.94
0.49 – 0.99	52	51	2.23	2.17
1.0 – 2.49	78	63	2.66	2.65
2.5 – 7.49	93	74	3.85	3.58
7.49 & above	96	79	6.68	5.42
Total	67	55	3.21	2.65

Source : BBS. Reports of Agricultural Census, 1983-84 and 2008.

Table 3
Trend in Real Wage Index in Bangladesh (deflated by rice price index), 1995 to 2010

Year	**Busy Agricultural Season**		**Slack Agricultural Season**	
	Male Worker	**Female Worker**	**Male Worker**	**Female Worker**
1995	138	91	109	76
2000	182	125	145	104
2005	171	109	135	91
2010	202	148	162	118
Rate of growth per year (%)	2.6	3.5	2.8	3.2

Source : Xiabo Zhang *et al.* 2014

Fourth, the agricultural labour market became tight with (a) rapid expansion of paved farm to market roads, (b) increased access to microcredit provided by NGOs, (c) growing opportunity for employment in non-farm activities, such as transport operations, and petty trade, and (d) opportunity for renting in land in the tenancy market with large and medium farmers leaving farming in favour of non-agricultural activities in rural and urban areas. As a result, agricultural wage rates started increasing rapidly since early 1990s (Table 3). The trend shows that agricultural wage increased at a faster rate than the rice prices, and the growth in real wages has been faster for female workers compared to that of the male workers. In 1995, the difference in wage of male worker in the peak season was 27 percent higher than in the lean season. The difference has increased to 36 percent by 2010. It shows increasing scarcity of labour during the busy agricultural season has grown over time. The female workers received two thirds of the wage paid to their male counterparts in 1995. The disparity has narrowed down to 27 percent by 2010. The numbers show that agricultural labour has become scarce over time. It provided incentives to farmers to go for labour-saving agricultural operations (such as use of herbicides for weed control), and renting machinery services from the market for services of mechanical power.

The upward trend in the operation of different agricultural machines can be noted from Table 1. The numbers show faster increase in agricultural machinery since late 1980s after the government introduced the policy of import liberalisation and decontrol of the market. The mechanisation happened earlier in irrigation, particularly through shallow tube wells and power pumps. The number of shallow tube wells increased six times during 1989-2014. The Minor Irrigation Survey conducted by BADC reports that the number of shallow tube wells increased from 260,000 in 1989/90 to 1.52 million in 2012/13, and the number of power pumps increased from 52,000 to 171,000 during that period. The farmers went for tillage and threshing machines later. The number of power tillers increased by 30 times and that of power threshers increased by 12 times within a decade from 1996 to 2006. The growth continued till 2012 (Table 1**).**The large machines that require heavy initial investment, such as tractors and deep tube wells are still not popular, despite the government promoting the import and distribution of machines by the private sector with 25 percent subsidies. It indicates that these are inappropriate technology in the context of the agrarian structure dominated by marginal and small farmers, and tiny parcels of land due to scattered farm holdings.

In the following sections we present findings of a farm household survey to assess the present situation of agricultural mechanisation in Bangladesh, and its impact on the cost of agricultural production. We cover three major machinery, namely shallow tube wells, power tillers and power thresher.

Sources of Data and Methodology

Survey on Operation of Selected Machines

We conducted a purposive sample survey to generate data on the ownership and operations of farm machinery, including sources of finance for acquisition of the machinery, the capacity utilisation of the machines, the nature of the rental market, and the rate of return on investment in the machines. The survey used as sample frame the branches of BRAC Tenant Farmer Development Project. We used a multiple stage random sampling method to select the farm households to be interviewed. In the first stage, we selected 50 percent of the bank branches where mechanisation is widely prevalent. In the second stage, we selected four villages from each branch from the list of all villages under operation. We then selected three machines from each village - one shallow tube well, one power tiller, and one power thresher for collection of information on the ownership and operation of each machine using a structured pre-tested questionnaire. The survey covered 25 districts and 94 sub-districts and 377 villages. Total sample consists of 1,128 farm machinery.

Sources of Data for Assessing the Effect of Farm Mechanisation

The study also uses un-published data set from a longitudinal repeat Sample Surveys that the first author has been generating and maintaining since 1987-88. The survey collected data from 62 randomly selected villages and the data were collected from same households from each village in 1987-88 and 1999-2000, 2004 and 2007-08 and 2014 (the surveys were sponsored by BIDS, IRRI and BRAC). A Multi-stage random sampling method was used with random selection of 64 unions from the list of all unions in the country, and one representative village from each selected unions. After selection of villages, a census of all households in the village was undertaken. Finally, 20 households (30 from 1999-2000 survey, and 40 in 2014 survey) were selected from each village form a Census of all households in the villages using a stratified random sampling technique. The stratification was done on the basis of wealth ranking of the households.

Findings of the Survey of Agricultural Machinery

Characterisation of Mechanisation

Table 4 provides information on the characteristics of the machine under operation, and the socio economic background of machine owners. The following points may be noted from the table.

Table 4
Characteristics of the Machines and Socio-Economic Background of Machine Owners, 2013

Indicators	**Shallow Tube well**	**Power Tiller**	**Power Thresher**
No of sample equipment	376	377	375
Percent acquired new	84	73	89
Average year under operation	6.9	4.0	4.4
Expected life of the machine (years)	15	12	12
Average age of machine owners (years)	41	39	41
Machine owners with below primary level education (percent)	47	52	48
Machine owners with farming as main occupation (percent)	96	92	95
Price of the machine (000 TK per unit)	20	120	54
Machine services rented to others (percent)	76	91	75

Source : Authors' own survey

The cost of acquisition of the machines was Tk 120,000 for power tillers, Tk 54,000 for power threshers, and 20,000 for shallow tube wells. Most of the machines under operation were purchased new. The machines which were procured from another user were 23 percent for power tillers (most costly machine among the three types), 16 percent for shallow tube wells, and 11 percent for power threshers. It appears that the machines that are within the affordable limit of the farmers purchased new.

The expected life of the machines is reported as 12 to 15 years. The average years of operation of the machine were 4 to 7 years. Most of the machine owners rented out the machinery services to other farmers. The machines that are exclusively used in the farm of the owners were 25 percent for shallow tube wells and power threshers, and only 9 percent for power tillers. Thus, a rental market for exchange of machinery services has developed for increased capacity utilisation of the machines. In Bangladesh, two thirds of the farms are below one acre size and 90 percent of the farmers operate land in sizes below one hectare (Hossain and Bayes, 2009); they cannot afford to invest in machines. More than 90 percent of owners of power tillers reported renting out services to other farmers in the village.

The average age of machine owners were 40 years, almost the same as the age of heads of the farms households. So the perception that only young people are taking up farm machinery service provision as a business venture is not validated by the survey. Almost 90 percent of the machine owners have farming as principal occupation, and almost half of them are either illiterate or had below primary level education. Thus, the ownership of the machines are widespread across socio-economic scales.

Table 5
Source of Financing of Investment in Agricultural Machinery, 2013
(percent of total cost)

Source of Finance	**Shallow Tube wells**	**Power Tiller**	**Power Thresher**	**All Machines**
Own savings	75.9	66.5	69.0	68.2
Remittance earning	2.1	3.7	0.7	2.8
Loan from NGOs	12.1	12.0	11.5	11.9
Loan from commercial banks	1.1	1.8	1.3	1.6
Friends & relatives	8.4	15.4	16.6	14.9
Traditional moneylenders	0.4	0.5	0.9	0.5
Total	100	100	100	100

Source : Authors' own survey

Table 5 reports the findings of the survey on the cost of financing for the investment in the machines. It may be noted that almost two thirds of the cost of the machines are financed from accumulated own savings of machine-owning households. The other major sources of finance for the acquisition of the machines are (a) mutual support system of friends and relatives (15%) and, (b) loans obtained from NGO led microfinance organisations (12%). Very few machines owners accessed credit from commercial banks to invest in the machines. The NGOs usually provide loans for one year, which is not appropriate for financing machines that have longer break even period. If MFI's had provided loan for longer period of time (three years or more), they could have been an important source of financing of agricultural machinery. Remittance from household members working overseas is found a major source of income of rural households (Hossain and Bayes, 2009). The finding that only 2.8 percent of the investment of the machines was financed from remittances (4 percent for power tillers and 2.8 percent for all machines) is surprising. Presumably, the savings from remittances (after use for consumption) are accumulated in personal savings. So, the use of remittances for financing machines is captured in the source of financing from personal savings.

The findings of the survey on the importance of different rental arrangement of the machines, and the rental charge for each arrangement are presented in Table 6. The services of the power tiller are rented out for tilling a particular piece of land (per bigha, *pakhi or katha* according local land measurement unit) and on the number of passes required for fine tillage of the parcel of land. But for shallow tube wells and power pumps several rental arrangements are in practice. For the shallow tube wells were introduced a crop sharing arrangement was the most prominent mode of hiring, with a rental charge of one-fourth of harvest given in lieu of irrigation services as many times as required during the crop season. This arrangement is now practiced in only 12 percent of the cases. The most common (53%) arrangement prevailing at present (2013) is fixed rental charge per season. The rental charge was Tk 12,000 (US $ 150) per acre. The rent is almost the same as Taka equivalent of crop sharing arrangement (15 maunds against the paddy yield of 60 maunds per acre), but the risk remains when the yield is lower due to natural disasters or pest attack is borne entirely by the farmers. To ensure that the risk is not passed on to the machine owner, the cash rent is collected in advance of the harvest.

Table 6
Rental Arrangements for Services of Agricultural Machinery and Rental Charge, 2013

Rental Arrangement	**Percent of Cases**	**Rental Charge/unit**
Shallow Tube wells		
Crop Sharing	12	25% of the crop
Seasonal Cash rent	53	Tk 12, 000 per acre
Hourly rent with farmer providing fuel Hourly rent if machine owner provides fuel	25 10	Tk 70/hour TK120/hour
Power Thresher		
Per maund (40 kg) of paddy	86	Tk 30/maund of paddy
Crop sharing	14	6.25% of harvest
Power Tiller		
Cash rent per unit of land	100	Tk 1130 per acre per pass

Source : Authors' own survey

Recently another practice is gaining popularity in the rental market. It is renting out of services of shallow tube well per hour of operation. The rental charge depends on who pays for the fuel. If the machine owner provides the fuel, the rent is Tk 120 per hour of operation; if the farmer provides fuel, the rent is Tk 70 per hour. This mode is appropriate for efficient use of water or for using supplementary irrigation during the *aus* (pre-monsoon) and *aman* (monsoon) season. In 2013, this arrangement prevailed in almost 35 percent of the cases. For power thresher, the predominant practice (77%) was paying cash rent per unit of land. The rental charge is Tk1130 (USD 15) per acre. In some areas, a crop sharing arrangement (6.25 percent of harvest) is practised for threshing services.

The information on gross income from renting out the machines is provided in Table 7. The rental income is the highest in the *boro* season; Tk 62,000 for power tillers, 34,000 for power threshers, and 28,000 for shallow tube wells. The shallow tube wells are rented out also in the *aman* season indicating growing practice of supplementary irrigation during droughts, even by farmers who do not own machines. The annual gross rent received was Tk 106,000 for power tillers, Tk 56,000 for power threshers and Tk 34,000 for shallow tube wells.

Table 7
Gross Return (Tk) from Rent of the Machines by Crop Season, 2013

Season	Shallow Tube wells	Power Tiller	Power Thresher
Aus	2, 301	6, 826	2, 475
	(6.8)	(6.4)	(5.0)
Aman	6, 006	37, 903	12, 880
	(17.8)	(35.6)	(25.8)
Boro	25, 398	61, 792	34, 495
	(75.4)	(58.0)	(69.2)
Total	33, 705	106, 521	49, 850

Source : Authors' own survey

The operation of the machines, however, involves some cost which needs to be deducted for estimating the net income from machine operation. The information is provided in Table 8. It can be noted that the major cost is on account of fuel which comprises 61% of total cost for power tiller, 53% for shallow tube wells, and 46% for power threshers. The second major cost component is on account of labour for operating the machines. The cost for labour accounts for 43% of the total cost for power threshers, 34% for shallow tube wells and 27% for power Tillers.

Expenses for repair and maintenance account for another 8 to 10 percent of total costs. Annual cost for operating the machines is estimated at Tk 60,500 for power tillers, 35,000 for shallow tube wells, and 30,000 for power threshers.

Table 8

Operational Cost (% of total) for the Machine by Component, 2013

Component of the cost	Shallow Tube wells	Power Tiller	Power Thresher
Fuel	53.0	61.2	45.6
Electricity	3.3	nil	0.1
Repair and maintenance	8.3	10.5	9.9
Wage bill for hired labour	10.1	16.2	26.2
Imputed cost for family labour	24.3	11.3	17.0
Other cost	1.1	0.9	1.3
Total operating cost (TK/machine)	35,192	60,490	29,879

Source : Authors' own survey

Table 9

Costs and Returns from Operation of Machine Per Year, 2013

Items	Shallow Tube wells	Power Tiller	Power Thresher
Rent received	33, 705	106, 521	49, 850
Imputed income for own use	17, 122	41, 937	25, 462
Gross income	50, 827	148, 458	75, 312
Depreciation of machine	1, 942	12, 024	5, 380
Operational cost	35, 192	60, 490	29, 879
Interest charge	5, 942	11, 602	5, 641
Total cost	43, 076	84, 116	40, 900
Profit	7, 751	64, 342	34, 412
Benefit/cost ratio	1.18	1.76	1.84
Time to recover the investment (year)	2.51	1.87	1.56

Source : Estimated from the machine level survey, 2013

The estimate of the net income from the operation of the machines is estimated in Table 9**.** The imputed cost of the use of the machine at rental prevailing in the market is about half of the gross income from renting out of the machine services for all types of machines. It appears that on average two thirds of machinery services are rented out. The cost of depreciation of the machines is estimated using the life of the machines as reported in Table 2. The net profit after deduction of all costs is estimated as Tk 64,000 for power tiller, Tk 34,000 for power threshers, and Tk 7,500 for shallow tube wells. The time to recover the investment on the machines is estimated as 2.5 years for shallow tube wells, 1.9 years for power threshers and 1.6 years for power tillers.

The Effect of Mechanisation

Incidence of Machine Ownership at the Farm Level

Table 6.10 provides information on the incidence of machine ownership by farm size. The data reveals that nearly 16% of the farmers own shallow tube wells, 12% own power threshers, but only 2% own power tillers. Few non-farm households invested in agricultural machinery.

Table 10
Changes in the Structure of Ownership of Agricultural Machinery, Farm Household Surveys, 2000 to 2008

Farm Size (ha)	Shallow Tube wells		Power Tiller		Power Thresher	
	2000	2014	2000	2014	2000	2014
Non-farm	1.0	1.5	0.0	0.7	0.3	0.7
Up to 0.4	2.2	10.3	0.2	0.5	1.6	3.5
0.4 to 1.00	14.8	32.0	1.6	4.4	6.2	8.5
1.00 to 2.00	32.3	51.2	4.3	13.3	6.7	15.7
2.00 to above	60.5	63.3	16.3	33.3	7.0	20.0
Total	8.2	13.9	1.1	2.5	2.5	4.3

Source : Estimated from data obtained from the longitudinal survey of 62 villages

The machines are mostly owned by medium and large farmers who operated land above one hectare. These are less than 10 percent of all farm households (Hossain and Bayes, 2010). But the investment on machines by small landowners has been growing, particularly for shallow tube wells and power threshers. In 2000, only two percent of rural households operating land below 0.4 ha (1.00 acre) owned shallow tube wells. The number grew to 10 percent by 2014.

What has been the impact of the use of farm machinery on the labour demand and cost of production? We may shed some on this question from the costs and returns data for the production of *boro* rice which is the most labour intensive crop. We have such data from the longitudinal repeat surveys but we noted that in 2014, almost all farms used power tillers and threshers. Since we have no control farmers who did not use the machines, we cannot estimate the effect of the use of farm machinery. So we used the data for the previous survey conducted for 2007-08 when still one-quarter of the farmers did not use power tillers or power threshers. Table 11 and 12 provide information on the cost of production of *boro* rice for the user and non-user of power tillers (Table 11) and power threshers (Table 12) in 2008. The input use and yield data show that the users of the machines are relatively progressive farmers as suggested by higher yields. It is surprising to find that those who used power tillers in fact used 4.3 percent more labour than the non-user farms. The cost saving occurred mainly in tillage operations from the non- use of draft power. The cost of production of one ton of rice was about six percent lower in the machine user farms, due to higher yields by about one ton of paddy per hectare and reduction in tillage cost on account of saving draft power from animals.

Table 11

Cost of Production of *Boro* Rice for User and Non-user of Power Tiller, 2008

Cost Items	**User (n=446)**	**Non-user (n=216)**	**Difference (percent over non-user)**
Material inputs	5, 360	4, 610	16.2
Irrigation	6, 274	5, 100	23.0
Tillage	624	1,180	- 20.1
Threshing	1, 880	1, 611	11.7
Labour days	146	140	4.3
Wage bill	9, 487	9, 091	4.3
Total cost	24, 881	21, 890	13.7
yield	5.54	4.61	20.2
Cost per ton	4, 491	4, 748	-5.5

Source : unpublished data from longitudinal survey

The costs and returns data for the user and non-user of power threshers are reported in Table 12**.** In 2008 *boro* season, almost half of the farmers used threshing machines which is much lower than the use of mechanised tillage. The mechanical thresher saved 12 days of labour, about 11 percent of the total labour used in *boro* cultivation. The major cost components are irrigation and labour. Irrigation charges account for about 29 percent of the total cost, and wage bill (including imputed value of family labour) accounts for about 40 percent of the total cost. Rental charges of power threshers account for only two percent of total cost. The unit cost of producing a ton of rice was 10 percent lower for farmers using mechanical threshers compared to the non-users of power thresher. The saving in unit cost was only 6 percent for using power tillers.

Table 12
Unit Cost of Production of *Boro* Rice, User and Non-user of Power Thresher, 2008

Cost Items	**User** (n=365)	**Non-user** (n=360)	**Difference** (per cost)
Material inputs	6, 721	7, 536	-10.8
Irrigation	8, 956	10, 848	-18.2
Tillage	2, 663	3255	-18.2
Threshing	1, 111	nil	-
Labour days	114	128	-10.9
Wage bill	14, 434	15, 393	-6.2
Total cost	33, 885	37, 127	-8.7
Crop Yield (ton/ha)	5.58	5.77	1.9
Unit Cost (TK per ton)	5, 762	6, 434	-10.4

Source : Estimated from the data set of longitudinal village studies.

Impact of Farm Mechanisation: Perception of Farmers

We sought opinion of the respondents on positive and negative effects of farm mechanisation. In the first response, the positive effects were stated as (in order of importance) timely and efficient farm operation (67%), reduced cost and increased profits (17%), and reduced losses or improved quality of grains. In the second response, important effects were perceived as reduction of cost and increase of profits (32%), timely and efficient operation (29%), reduction in losses and improvement in quality of the produce (20%), and reduced drudgery (14%). If we take multiple responses, positive effects in order of importance were stated as timely and efficient operation, reduction of cost and increase in profits, reduction of losses and improvement in the quality of the grains, and reduction of drudgery. Only five percent of the respondents stated that the use of machinery had increased cropping intensity.

Only a few respondents reported negative effects of mechanisation. The perceived negative effects are degradation of environment from intensive use of fossil fuel (the machines are run by diesel), high repair and maintenance cost, unemployment of workers depending on wage labour, shortage of finance for acquisition of machines by low-income households, shortage of skilled labour for the operation of the machines, and increase in the cost of fuel, in that order of importance.

Conclusions

The government has long been promoting agricultural mechanisation through farmers' cooperatives to reap economies of scale. With the exception of mechanisation of irrigation through power pumps and shallow tube wells, the success in reaching agricultural machinery to farmers remained limited till late 1980s. The policy of liberalisation of agricultural input markets in late 1980s, the removal of ban on the import of machinery by the private sector, and the elimination of import tariffs on diesel engines gave a boost to private investment in farm machinery. Growing scarcity of draft animals, rising cost of fodder, and increase in real wages for agricultural labour gave further boost to private investment in machinery over the last two decades.

The ownership of machines is mostly in the hand of medium and large landowners. The investment in machines are financed mostly by own savings. The micro-credit has played limited role in financing mechanisation because of the practice of giving loans for the duration of one year which is less than the break even period for investment in machinery. A rental market for machinery services has developed to provide access to services to small and marginal farmers who cannot afford to own the machines. The investment in farm machinery is highly profitable. The cost of investment is recovered within two to three years.

The positive effect of mechanisation as perceived by the respondents are timely and efficient farm operation, increased profit, reduction of drudgery, and reduction of postharvest losses and improved grain quality. However, it is also perceived by some that farm mechanisation has had negative effects in terms of environmental degradation.

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Chapter 7

Status of Agricultural Machinery Manufacturing in Bangladesh

Md. Monjurul Alam and Imanun Nabi Khan

Introduction

Bangladesh agriculture was absolutely dependent on tradition and nature until the introduction of Mechanised Cultivation and Power Pump Irrigation (MCPPI) scheme in 1950-51 by the Agricultural Directorate, which was the first known attempt of using machines in the field of agriculture in the country. During 1960-65, the government distributed several thousand power pumps, tractors, sprayers and dusters, and established two workshops at government level. Later in 1970, international charitable organisations provided several thousand tractors and power tillers to the affected farmers to cope with the draught power shortage caused by the devastating cyclone at the coastal areas of the county. Local engineering workshops that were engaged with repair and maintenance of the imported machinery gradually emerged in the market and soon started producing small spare parts with limited resources and skills. That was the landmark for manufacturing of agricultural spare parts and equipment in the country.

In 1970s, the changes in cropping pattern and cropping intensity due to introduction of HYV rice crop increased a demand for mechanised irrigation, tillage, pest management and postharvest processing of crops to attain timeliness of operations. The power pumps and power tillers gradually gained popularity in spite of difficulties encountered with after sales services, repair facilities and training of operators. Although, switching over to mechanical power from animal and human muscle power was insignificant during this period.

However the practice of importing only high quality standardised machines and equipment also restricted the market to a limited makes and models of high quality and relatively high priced imported equipment. Later, the heavy loss of draft animals due to a devastating flood in 1988, the government promptly liberalised machinery import policy, which resulted in huge of import of agricultural machinery in the country, such as power tillers, diesel engines, and motors.

As a result of this policy change, in 1990s, agricultural machinery sub-sector had gone through remarkable diversification of activities like repair, maintenance and manufacturing of farm implements, machines and spare parts for irrigation pumps, engines/motors, power tillers, sprayers, pedal and engine operated paddy and wheat threshers, maize shellers, rice hullers, poultry and dairy equipments, etc. There are about 2,000 small to medium size agricultural machinery manufacturing enterprises in the country, providing immense contribution to this sector. Alongside of these manufacturing workshops, repair & maintenance of agricultural machines and equipments were provided by 10,000 small engineering workshops and approximately 500,000 mechanics (Alam, 2005).

This study made an attempt to take account of agricultural machinery and spare parts manufacturers, importers, traders/wholesalers and retailers and their associations, assess market potential for agricultural machinery and spare parts' industry and identify serious bottlenecks associated with this sub-sector.

Methodology

The study was planned and designed to make an assessment of the agricultural machinery and spare parts industries in the country through survey of manufacturers and Focus Group Discussions (FGDs) with key actors of the sub-sector. The survey on manufacturers was conducted based on stratified random sampling technique. Appropriate tools for FGDs and survey instruments were developed to conduct the study.

Present Status of Manufacturing and Marketing of Agricultural Machinery

In recent past, significant improvements have been made in the production and marketing of locally made agricultural machinery in the country. Eventually, almost all centrifugal pumps being used in Shallow Tube wells (STW) and Low Lift Pumps (LLP) are manufactured in the country. Similarly, paddy and wheat threshers, maize shellers, hand and foot-pump sprayers, weeders, engine and machine spare parts are also being manufactured locally. However, this sub-sector is still recognised as non-formal sector and very limited effort has been made so far to assess the sub-sector market demand

and supply, Available information on present market demand and supply status, and export potential of selected agricultural machineries are presented in the following sections.

Table 1

Annual Market Size (in million US $) of Agricultural Machinery in 2011

(1 US $ = BDT 80.0)

Agricultural Machineries	**Market Size/yr**
Power tiller (Imported)	50.0
Tractor (Imported)	80.1
Engine (Imported)	256.9
Tillage machinery	9.7
Centrifugal pump (STW & LLP)	16.7
Spare parts (Local)	237.9
Spare parts (Imported)	71.4
Sprayer (local)	1.5
Sprayer (Imported)	0.4
Thresher (Open & Close drum)	39.5
Maize sheller	1.3
Weeder	0.6
Harvesting equipment (Imported)	1.2
Rice milling machinery (Imported)	35.1
Sub-total	802.3
Repair & Maintenance	105.2
Total market size	907.5

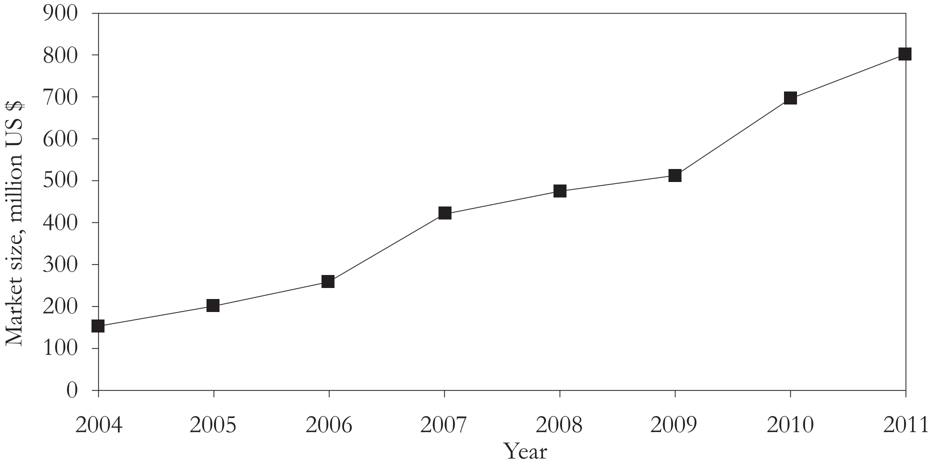
Source : Authors' estimates from various sources.

In recent years, there have been about 70 foundries, 800 agricultural machinery manufacturing workshops, 1,500 spare parts manufacturing industries and workshops and about 20,000 repair and maintenance workshops engaged in agricultural machinery sub-sector of the country. The machinery need for production and postharvest processing of crops has increased significantly in recent time. Despite limitations, the sub-sector is growing quite satisfactorily and has potential to grow faster. Table 1 depicts the existing annual market size of some selected agricultural machineries. The annual estimated market size of agricultural machinery and spare parts in the country is about US $ 802.3 million with an US $ 105.2 million annual repair and maintenance service market, estimating an annual total agricultural machinery market size of about US $ 907.5 million of which local production and repair & maintenance market share is about US $ 402.7 million (44%) in 2011. The market has further expanded in the recent years..

Since early nineties, the demand of agricultural machinery in the country increased and the market grew rapidly since then. The market grew more than three folds from US $ 273.6 million annually in 2006 to US $ 802.3 million in 2011 (Figure 1). This trend provided significant boost to the local production of agricultural machinery and spares parts and decreased dependency on import.

Figure 1

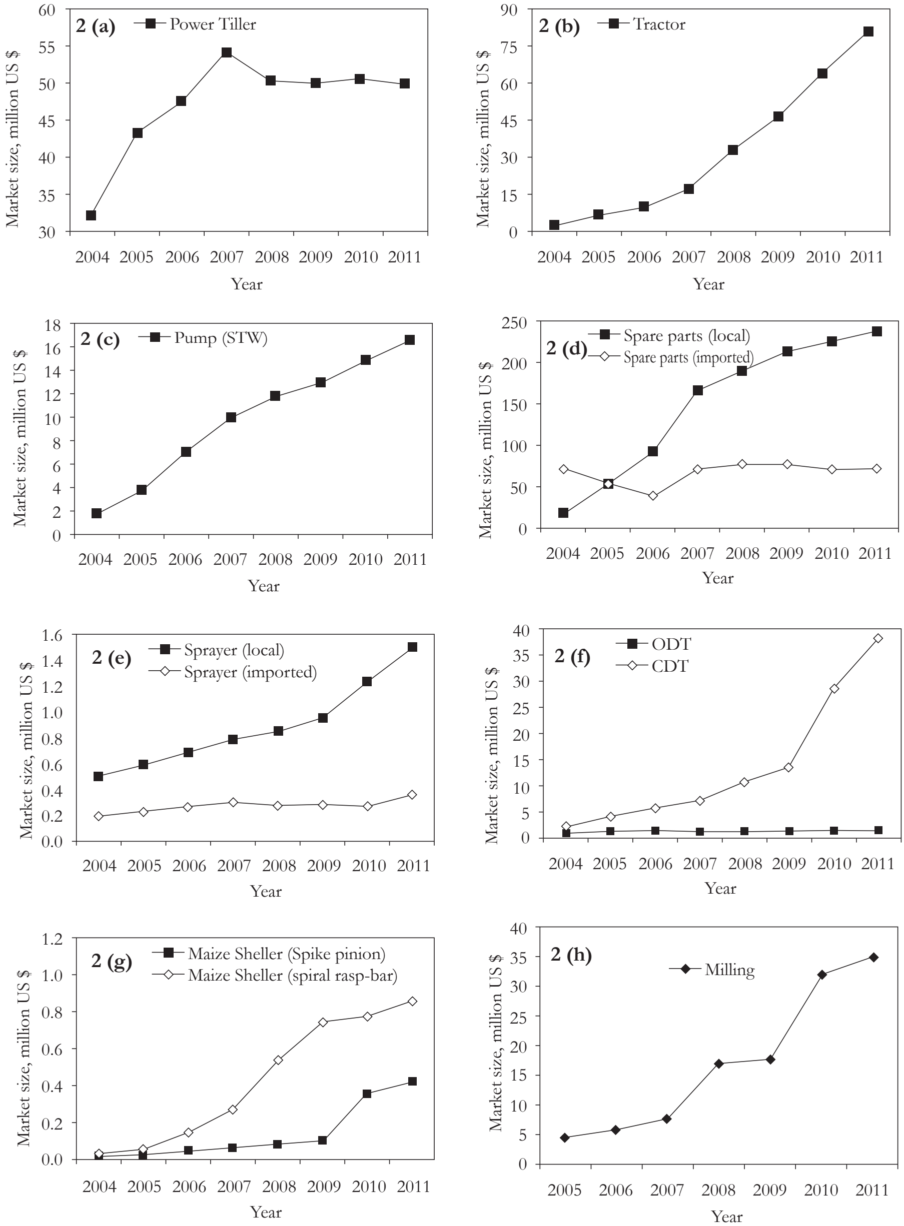
Agricultural Machinery Market Trend in Bangladesh



The supply of power tiller (PT) solely depends on import. There are about 5,50,000 PTs operating in the country. During 2004 to 2007 about 55,000 to 60,000 PTs were imported annually, later the import trend slowed down gradually and during 2010-11 about 42,000 power tillers were imported annually worth US $ 50.0 million (Figure 2a). The supply chain of power tiller involves importers, wholesalers and retailers. Five Dhaka based large importers are the major sources of supply of PTs to district level wholesale and retail market. About 95% of the PTs are distributed to wholesalers and retailers at district level and 5% being retailed by the importers themselves through company showrooms. On the other hand, district wholesalers and retailers are retailing 70% at district market and 30% to other districts and Upazila level markets.

Figure 2

Trends of Different Agricultural Machineries Market in Bangladesh



The supply of tractors in the country totally depends on import. At present, there are about 35,000 tractors operating in agricultural sector, mainly for tilling and transportation purposes. The number of tractor import has increased rapidly and side by side with the use of power tillers in agricultural sector. Presently, on an average, 6,200 four- wheel tractors mostly from Indian origin worth US $ 80.1 million are being imported annually in the country mostly from Indian origin. The supply chain of tractor involves importers and retailers. Few private sector companies like The Metal, ACI Motors Ltd., Mahindra, Corona, etc. are importing majority of the tractors and marketing through its dealers and own showrooms at different district towns and business centres. Most of the tractor companies are providing after sales services to the buyers.

The supply of centrifugal pumps for STW and LLP depends on local production. In 2010, there were about 1425,136 STWs and 150,613 LLPs operating in Bangladesh (BADC, 2010) with an annual demand of 850,000 centrifugal pumps. However, the present production volume of centrifugal pump is about 560,000 units with an annual turnover of US $ 16.6 million (Figure 2c). Based on unmet demand, a potential market size of US $ 5.6 million is remaining unexplored. Bogra district alone is producing about 90% of the centrifugal pumps and its accessories followed by Dhaka and Jessore districts. However, the manufacturing of centrifugal pump is facing many odds. The major constraints are the use of age-old machineries and technologies resulted in quality-compromised products, high price of raw materials, poor quality of raw materials, inadequate skill and technical knowledge related to metal casting and heat treatment, lack of testing facilities for maintaining quality of products, inadequate working capital, lack of non-interrupted supply of electricity, inadequate spaces for the manufacturing industries, inappropriate tariff policies on import of spare parts and raw materials.

Spare parts of power tiller, diesel engine and centrifugal pump are imported and locally produced as well. A significant amount of spare parts is being produced in the country, especially in Bogra, Dhaka, and Jessore districts. The estimated market size of spare parts in the country was about US $ 89.2 million in 2004-05 of which local production size was about US $ 1.78 million (Alam, 2005). In contrast, the market size of spare parts in the country during 2011 was about US $ 309.3 million of which the share of local production was about US $ 237.9 million, according to the representatives of the Bangladesh Agricultural Machinery Manufacturing Association (BAMMA), Foundry Owners' Association (FOAB) and Bangladesh Shilpa Malik Samity (BSMS) participating in a policy workshop held at the Rural Development Academy (RDA), Bogra in 2011. This significant shift in the supply of spare parts in the country underlines the growth potential of the local spare parts manufacturing sub-sector and potential for substitution of imported spare parts. This saves a huge amount of foreign currency and decrease dependency on import. Bogra alone has produced about 80% of the local spare parts, other 20% is being produced in Dhaka and Jessore districts. The spare parts sub-sector is employing a significant number of skilled and semi-skilled labour forces, and creates opportunities for further employment. However, this sub-sector is yet to get the attention of the policy planners of the country.

The import channel of spare parts involves importers, district wholesalers and retailers. On the other hand, local spare parts production channel has two sub-channels. One, an integrated foundry and spare parts machining unit and the other is independent foundry and machine shop units . The market trend shows that the integrated sub-channel has got major market share compared to non-integrated sub-channel.

Among spare parts, piston, and liner production has a significant share in the domestic market as well as export market in Nepal, Bhutan, and India. A comparative scenario of price and quality of major local and imported spare parts is shown in Table 2. Some locally produced spare parts such as, centrifugal pump, impeller, fuel filter, rocker arm, PT chain cover, pulley, etc. are very good in quality and captured the local market by replacing imported China spare parts. Among many local spare parts piston, liner, clutch bush, governor bush, housing, silencer, chain cover, bush guide, etc. are cheaper in price and good in quality as compared to imported spare parts and have good market potential in the country. In competing with the imported spare parts, the sub-sector faces many constraint; , the main constraints are high price and inadequate supply of quality raw materials, lack of modern capital machinery, inadequate skill and knowledge related to production, lack of market and technical information, inappropriate policy related to custom duties, VAT, etc for imported raw materials..

All types of hand and foot sprayers are produced locally. Only knapsack sprayers are imported from China, Korea, Brazil and India. The local manufacturers collect raw materials from Dhaka market and sell 30% product to own district market and 70% to other district markets. The annual demand of locally produced hand and foot sprayers is about 3,00,000 pieces worth US $ 1.5 million The market size of imported knapsack sprayer is about US $ 0.4 million per annum. The sprayer production units are facing some constraints such as high price and lack of quality raw materials, inadequate skill and knowledge related to production, lack of market information etc.

Table 2
Comparative Quality and Price (in US $) of Few Selected Spare Parts

Item	Local Spare Parts		Imported Spare Parts		
	Quality	Price	Quality	Price	Country
Liner (C-25)	Good	6.19	Not good	8.92	China
Liner (C-20)	Good	5.35	Not good	8.33	China
Liner (C-12)	Good	5.35	Not good	7.73	China
Piston (C-25)	Good	5.95	Good	6.66	China
Piston (C-20)	Good	5.35	Good	5.47	China
Piston (C-12)	Good	3.81	Good	4.28	China
Gudgeon pin (C-25/24/20)	Very good	1.55	Good	1.43	China
Gudgeon bush(C-25/24/20)	Very good	0.71	Good	0.59	China
Head Gasket (C-25)	Good	0.71	Very good	1.07	China
Head Gasket (C-20)	Good	0.59	Very good	0.83	China
Head Gasket (C-12)	Good	0.36	Very good	0.42	China
Head set	Very good	0.24	good	0.24	China
Valve guide	Very good	0.36	good	0.30	China
Fuel Filter	Very good	0.18		No import	
Racer arm	Very good	0.42		No import	
Pump 3 "	Very good	26.17		No import	
Pump 4 "	Very good	34.50		No import	
Pump 5 "	Very good	39.26		No import	
Impeller 3 "	Very good	1.43		No import	
Impeller 4 "	Very good	2.97		No import	
Impeller 5 "	Very good	3.81		No import	
Oil seal (50 x 80 x 12)	Good	0.30	Very good	0.42	China
Air cleaner 12/16 hp engine	Good	3.57	Very good	7.14	China
Air cleaner 8.5 hp engine	Good	2.14	Very good	4.76	China
Air cleaner 6 hp engine	Good	1.19	Very good	3.57	China
Silencer 12/16 hp engine	Good	3.09	Good	4.16	China
Silencer 8.5 hp engine	Good	1.90	Good	3.33	China
Silencer 6 hp engine	Good	1.78	Good	2.97	China
Chain cover	Very good	5.95	Good	7.14	China
Bush guide	Very good	0.24	Good	0.18	China
Washer	Excellent	0.18	Not good	0.08	China
PT tine nut	Good	0.30	Very good	0.36	China
PT chain cover	Good	6.54		No import	
PT pulley	Good	4.52		No import	
V - pulley	Very good	2.38		No import	
Fuel key	Excellent	0.89		No import	
Fuel pipe	Good	0.48	Very good	0.71	China
Oil catcher (Kubuta-900/600/550/90)	Very Good	0.83		No import	
Oil catcher (Mitsubishi-110/90/75)	Very good	4.16		No import	
Clutch Bush	Very good	0.30	Good	0.30	China
Governor bush (big)	Very good	0.95	Good	0.83	China
Governor bush (small)	Very good	0.24	Good	0.18	China
SF arm pipe	Very good	2.38		No import	
SF pulley tension set	Very good	1.90		No import	
6209 housing	Very good	1.55	Good	1.49	China
6207 housing	Very good	1.55	Good	1.49	China
6307 housing	Very good	1.19	Good	1.19	China
6311 housing C/6	Very good	2.97		No import	
Fuel tank 8.5 hp engine	Very good	12.49		No import	
Fuel tank 6 hp engine	Very good	10.71		No import	
Fuel tank 4 hp engine	Very good	10.11		No import	

Note : Price list is based on a survey in 2011

The supply of paddy and wheat threshers totally depends on local manufacturing. The manufacturers collect raw materials mostly from local market and sell, on an average, 30% at local market and 70% to other district and Upazila markets. The numbers of open and closed drum threshers in the country already exceeded 150,000 and 220,000, respectively. The annual demands of open and closed drum threshers are about 20,000 and 80,000 units worth US $ 39.5 million.

The demand of thresher is increasing and its production does not face any competition from import. The production of threshers are facing some constraints, the most common are inadequate skill and knowledge related to production, high price and inadequate supply of raw materials, lack of market and technical information, inappropriate policy related to duties on imported raw materials, etc.

The supply of maize sheller also depends on local manufacture. The manufacturers collect their raw materials mostly from local market and sell on an average 25% at local market and 75% to northern district markets of Bangladesh. The unit price of spike-pinion type maize sheller is about US $ 119 and the price of spiral rasp-bar cylinder type maize sheller ranges between US $ 309.3 and US $ 380.6. The present population of maize sheller in the country is about 18,100 with an annual demand of 6,500. The present market size of maize sheller is estimated about US $ 1.3 million per annum.

The demand of maize shellers is increasing rapidly with the increase in maize crop area and increased production in the country. The main constraints faced by maize sheller manufacturing are high price and inadequate supply of quality raw materials, inadequate skill and knowledge related to production, lack of market and technical information, inappropriate policies related to duties, VAT, etc. on imported raw materials. The quality of manufacturing and the profit margin may further improve by introducing automation in drilling holes on cylinder concave, cutting and bending of metal sheets and plates with scale up production practice and management.

In order to overcome scarcity of labour in harvesting and planting seasons of paddy and wheat, rice transplanter, self-propelled reaper and medium size combine harvester have high demand among the farmers. Few importers namely ACI motors, the Metal, etc. have started importing rice transplanter and combine harvester from Korea and popularising among the farmers. The present import market size of harvesting machines is about US $ 1.2 million. Two engineering workshops, namely Janata Machine Tools Ltd. of Jessore and Mahbub Engineering Workshop at Jamalpur fabricated few units of BAU model (Hossain, 2002) self-propelled reaper for commercial purposes each costing US $ 892. The field capacity and efficiency of this machine is 0.21 ha/hr and 81%, respectively with a cost saving of US $ 17.5/ha over manual harvesting of paddy. There is a huge demand for reaper in the country but the local manufacturers are facing difficulties in maintaining the precisions needed in manufacturing and thereby unable to meet the standard required for marketing of the reaper.

Rice milling in the country is overwhelmingly mechanical and there are about 15,239 husking mills, 350 semi-automatic and 300 automatic rice mills in the country, according to the Rice Mill Owners' Association source in 2012. In addition, there are about 100,000 traditional Engleberg type rice hullers in the country. Recent studies identified that the number of rice husking mills are shrinking and the businesses are being shifted either to semi-automatic or to automatic rice mills. These modern rice mills are using mechanical technologies, like pre-cleaning, parboiling, drying, milling, paddy separating, polishing, de-stoning, silking, colour sorting aerating, bagging, weighing & sewing. The annual import market size of these machines is estimated as US $ 35.1 million .

Besides most common agricultural machinery and spare parts production, a few items like drum seeder, push-pull weeder, potato harvester, potato grader, fish and poultry feed machine, rice grader, rice polisher, auto crusher machine, auto mixture machine, oil mill, chira/puffed rice mill, rice huller, hot mixture machine, cereal dryer machine, etc. are being manufactured in the country. This sub-sector remains unexplored and there is a huge potential for growth and employment generation.

Alongside of manufacturing of agricultural machinery and spare parts, there are about 20,000 repair and maintenance workshops and about 5, 00,000 mechanics are involved in repair and maintenance of engines and machines used in agricultural activities worth of about US $ 105.2 million service market annually.

Supply Chain of Agricultural Machinery Sub-Sector

A common supply chain of agricultural machinery sub-sector in Bangladesh is delineated in Figure 3, which involves importers, raw material traders, foundry or foundry cum agricultural machinery manufacturers, spare parts manufacturers, wholesalers, and retailers. The channels are identified based on the core business unit i.e., the producers. In forward linkage, the channels are up to the consumers i.e., the farmers. On the other hand, in backward linkage the channels go down to the importers. The common supply chain of agricultural machinery maintains three core channels, namely (i) imported agricultural machinery, diesel engine, spare parts and raw materials channel; (ii)local agricultural machinery production channel; and (iii) local spare parts production channel. The core business units are fragmented and small. In general, the more integrated (foundry and machine shop under the same shed/factory) the units, the more capital-intensive they are. The integrated units also have fewer intermediaries and mostly have their own outlets for both wholesaling and retailing.

Constraints of Agricultural Machinery Manufacturing and Business Development Service (BDS)

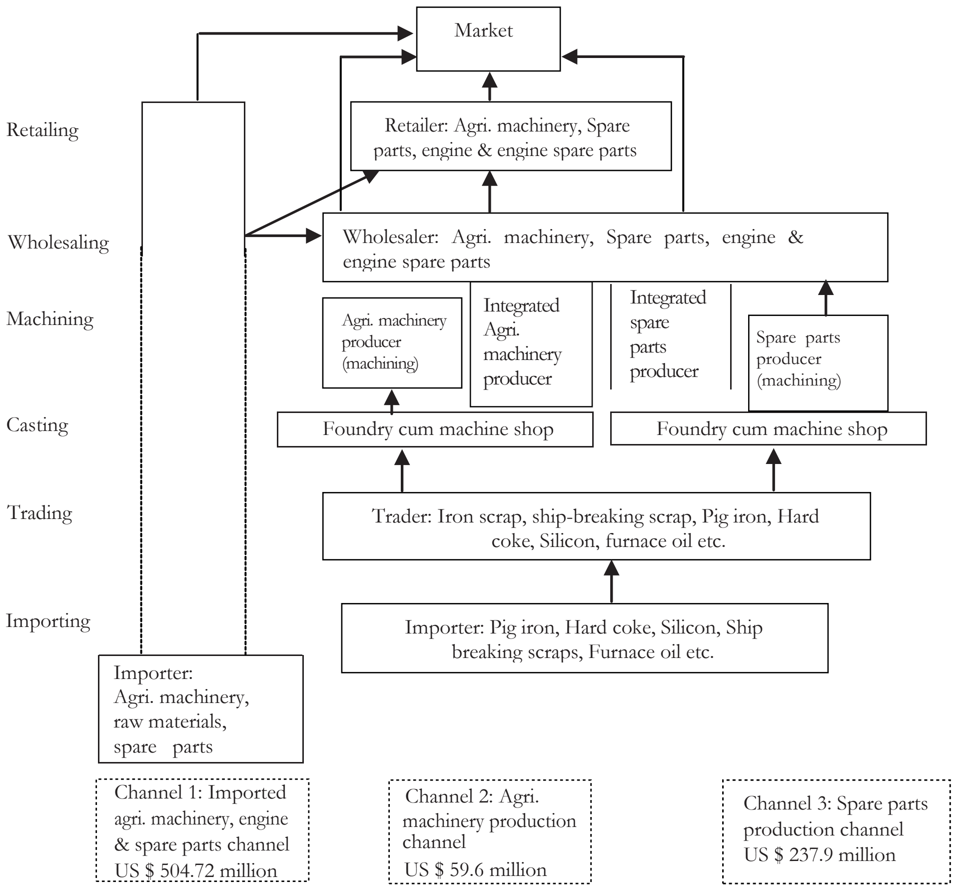
As an emerging sub-sector, agricultural machinery manufacturing faces many constraints. However, major constraints that have grave implications on the growth of the sub-sector are illustrated in this section.

Lack of Modern Capital Machinery at Producers' Level Result in Low Productivity and Poor Quality of Products

Agricultural machinery sub-sector is comprised of small and medium size enterprises. They emerged mostly from repair and maintenance service sector and lacking of modern capital machinery. Mostly, the enterprises are depending on age-old outdated machineries for manufacturing agricultural machineries and spare parts. As a result, these are producing quality compromised products and face tough competition with the imported machines and spare parts from abroad, especially products from China.

The enterprises are also lacking information about appropriate capital machines and equipment suitable for production of quality machines and spare parts; there are also lacking of appropriate design, drawing and manufacturing processes; and lacking of knowledge about the sources of these technical information. Awareness building programme along with appropriate policies for soft credit facility and low tariffs on modern capital machinery import are suggested for a break-through in this sub-sector.

Figure 3
Common Supply Chain of Agricultural Machinery Sub-Sector



Inadequate Supply of Quality Raw Materials to the Foundries and Manufacturing Workshops Hampers Production and Increases Production Cost:

Foundries, pump and spare parts manufacturers solely depend on the supply of imported raw material such as pig iron, ship breaking scraps and local scrap iron, steel, brass etc. The enterprises also depend on imported hard coke and furnace oil. The supply of old ships for ship breaking industries decreased in recent years due to international competition, especially in competition with China and India. Moreover, it is widely perceived that business collusion among few importers, based in Chittagong and Dhaka controls the import of these raw materials. Most entrepreneurs strongly believe that these syndicates are manipulating the supplies of ship breaking scraps and hard coke, and responsible for price hike. In 2010, the prices of ship breaking scraps and coal were increased to US $ 0.54/kg and US $ 0.74/kg, respectively that generated sensation among the business communities. The crisis intensifies with multiple VAT on raw materials and finished products at different stages of sales. Furnace oil supply in border districts such as Jessore and Dinajpur is restricted by *'kota'* system. As a result, small foundries are hard hit at peak demand, as they are unable to stockpile the furnace oil in time due to inadequate working capital. The high price and unavailability of quality raw materials poses a great threat to the domestic agricultural machinery and spare parts production in terms of production cost and quality as compared with the imported machines and spare parts, especially for those imported from China.

Lack of Skill Slows Manufacturing and Results in Low Productivity of the Sub-Sector

Most of the agricultural machinery entrepreneurs are lacking appropriate knowledge and skill on heat treatment, metal casting and fabrication of agricultural machinery products. Qualified engineers, even diploma engineers in the sub-sector having knowledge and skill related to design, drawing, manufacturing process and quality control are scarce. The scarcity of skilled and competent personnel in the sub-sector has increased the tendency of migration of such workforce from one enterprise to another. There are some, who join an enterprise strictly for gaining experience. They eventually leave the organisation with a view to starting their own operation with the limited capital at their disposal. The growth of mostly inexperienced small enterprises is causing poor business in the enterprises e.g., low quality output, low productivity, non-delivery of products in scheduled time, increased wastage of raw materials, etc. These in fact are inflicted with poor profitability and low quality outputs of the enterprises and as a whole slows down the growth of the sub-sector.

Lack of Steady Supply and Rationing of Electricity Restricts the Production and Business at Producers and Farmers Level

Frequent load shading of electricity causes a severe problem in production and marketing of products. Machines used in manufacturing of machines and spare parts are mostly operated by electricity. In recent time, a significant number of pumps used for irrigation are also operated by electricity and frequent load-shading in peak hours causes a significant loss in crop production. In 2011 irrigation season, the government had issued mandatory shutdown of commercial places and markets including agricultural machinery and spare parts manufacturing industries and workshops after 8:00 pm, this is done to save on electricity and to allow the irrigation pumps to operate unhindered. The electricity rationing policy also included Mondays as the weekly holidays in industrial sector instead of Fridays in Bogra. This virtually reduced the industrial working days into five in a week, as workers like to have holiday on Fridays for saying 'Jumma' prayer. No doubt, it is a national priority. However, the supply of irrigation water to the boro crop does not only demand electricity but also the steady supply of pumps and engine spare parts. Therefore, the production units of agricultural machinery and spare parts must be kept beyond these restrictions for the sake of uninterrupted production of pumps and spare parts for irrigation equipment. Moreover, the agricultural machinery manufacturers have to pay at the industrial rate for electrical energy. As a priority sector, the energy rates must be subsidised to keep the market price of the agricultural machinery and spare parts within the purchase capacity of the farmers.

Lack of Testing and Standardisation Facility Hinders Production of Quality Agricultural Machinery and Spare Parts

The existing agricultural machinery and spare parts industries and workshops in the country do not have standardised quality control facilities to ensure quality of products. Inexpensive quality control measures are being introduced in some agricultural industries but some expensive quality test and operation facilities, such as testing of metals and alloys, performance test of pumps, heat treatment of metals and alloys, etc. cannot be owned by small agricultural industries and workshops. There should be a common facility in every major public or private centre of agricultural machinery and spare parts production

Inadequate Working Capital Hinders Production in Agricultural Machinery and Spare Parts Industries and Workshops

The demand of agricultural machinery is mostly seasonal. Most of the enterprises in this sub-sector are very small in size and lack sufficient working capital for production in off-season and maintain stock for the peak season. Only in centrifugal pump production sub-sector in Bogra has US $ 5.65 million unmet market size because of limited supply in peak period of demand. This sub-sector needs medium term soft credit facility from government and private sector banks, financial institutions and cooperatives. Recently, Bangladesh Bank has allocated US $ 4.76 million with a 10% interest as an incentive to Bogra agricultural machinery sub-sector. However, the commercial banks disbursed this incentive only to their clients who have reputation as agricultural machinery producer.

Lack of Space and Infrastructural Facilities Hinder Growth of this Sub-Sector in Bogra

Bogra is identified as the centre of agricultural machinery and spare parts production and marketing. Almost 80% of the agricultural machinery and spare parts production in the country comes from Bogra hub. However, the industries have grown scattered in Bogra town, especially in Bangladesh Small and Cottage Industries Corporation (BSCIC) compounds. However, Goail Road, Railway Market and BSCIC industrial area are too small to accommodate the number of agricultural machinery and spare parts industries established in and around Bogra town. In Railway Market and Goail Road, the manufacturing workshops have hardly any infrastructural facilities and spaces favourable for production. The workshops do usually operate in very congested and unhealthy locations. It is suggested that these workshops should be shifted to a specialised zone e.g., 'Agricultural Machinery Production Zone (APZ),' similar to EPZ at the outskirt of Bogra town.

Lack of Market Information at Producers' and Sellers' Level Resulting in Slow Growth of the Sub-Sector

Most of the enterprises of the sub-sector are small and have limited capacity for gathering market information, such as size of market, cluster of market and potential for export. The promotional efforts on the part of the producers and sellers are generally confined to personal relationship. As a result, the sub-sector registered a slow growth, although there is a huge unexplored potential for expansion of the market. The producers estimate their production size depending on the sale of previous year and little information gathered through their customers at different districts and upazilas. Formal market survey is beyond most enterprises financial and logistics ability. Marketing of most of the agricultural machines and spare parts are localised. However, pump, piston and liner manufacturers have developed few non-formal channels throughout the district towns of the country. Few piston and liner producers have non-formal channels for export to Nepal and Bhutan. However, huge potential for export of piston, liner, pumps, sprayers, spare parts, etc. still remains unexplored. In recent time, few potential manufacturers are trying to explore the export market of pumps and spare parts to India. Removal of tariff and non-tariff barriers from Indian side through state negotiation can create a favourable condition for export and growth of this sub-sector. Capacity building of the enterprises regarding market information and expansion of the market is another issue. Recently, Bangladesh and India have established border markets (*hats*) for the benefits of the people of both the countries. Allowing formal trading of agricultural machinery and spare parts at these markets may further strengthen border trade and expansion of agricultural machinery market to India.

Lack of Ability to Collectively Safeguard the Interest of the Sub-Sector Results in Inadequate Reflection of the Needs and Expectation of the Sub-Sector

The development and growth of the sub-sector is comparatively new and mostly comprises of small to medium enterprises. As a result, coordination among the sub-sector actors is practically non-existent. In recent time, Foundry Owners' Association of Bangladesh (FOAB), Bangladesh Shilpa Malik Samity (BSMS) and Bangladesh Agricultural Machinery Manufacturers Association (BAMMA) are in action in the sub-sector, but a small portion of the actors are actively associated with the activities of the associations; which limits the lobbying and advocacy activities of the associations to influence various policy formulating bodies. Capacity building of the associations is an urgent need for the growth and development of this sub-sector.

The major constraints of agricultural machinery sub-sector along with Business Development Service (BDS) provisions and potential service providers are illustrated in tabular form below (Table 3).

Table 3
Agricultural Machinery Business Development Services

<table>
<tr><th></th><th>Constraints</th><th>Business Development Services</th><th>Service Providers</th></tr>
<tr><td rowspan="5">Skill Development</td><td rowspan="4">• Lack of skill related to iron, alloy and brass casting, heat treatment; fabrication and machining; R & M of agricultural machinery; and marketing and financial management training at the producers' as well as service providers' level</td><td>• Provisions for skill development on iron, brass and alloy casting, and heat treatment of metals to workshop and foundry technicians</td><td>Public sector training institutes: BITAK, BUET, BMTF, Development partners</td></tr>
<tr><td>• Provisions for skill development on machine fabrication and machine operation to workshop technicians</td><td>Public and private training institutes; Manufacturing workshops; DFPM of BAU</td></tr>
<tr><td>• Provisions for knowledge and information on basic operation, repair and maintenance to farmers, custom-hire service providers and mechanics</td><td>Private training institutes; Manufacturing workshops; DFPM of BAU</td></tr>
<tr><td>• Provisions for skill development on marketing and financial management to management personnel</td><td>Public and private training institutes</td></tr>
<tr><td>• Inadequate ability to collectively safeguard the interest of the sub-sector</td><td>• Provisions for strengthening capacity of Foundry Owners' Association of Bangladesh (FOAB), Bangladesh Shilpa Malik Samity (BSMS) and Bangladesh Agricultural Machinery Manufacturers Association (BAMMA)</td><td>Business associations, Development partners, NGOs</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">• Inadequate information related to market size and cluster, and production technology at producers' level
• Lack of Bangla operation and maintenance manual of agri-machinery for mechanics, custom-hire service providers and farmers</td><td>• Provisions for access to market information about market size, clusters of market and potential for export market to producers and sellers</td><td>Agri-machinery business associations, GO (Ministry of information and foreign affairs), Development partners</td></tr>
<tr><td>• Provisions for easy access to Bangla operation and maintenance manual to mechanics, custom-hire service providers and farmers</td><td>Private firms, NGOs</td></tr>
</table>

	Constraints	Business Development Services	Service Providers
Product development	• Lack of modern capital machinery • Lack of testing and standardisation facilities in Bogra and Jessore • Inadequate innovation and continuation of agricultural machineries	• Provisions for access to information on modern technology and capital machinery	BUET, BAU, BRRI, BARI, GO, NGO, Development partners
		• Provisions for establishing common facility centres for testing and standardisation in Bogra and Jessore	GO, Private sector, Development partners
		• Provisions for establishing 'Central Institute of Agricultural Engineering (CIAE)' for continuation of innovation through R&D	Government, Development partners
Input supply	• Lack of supply of quality raw materials	• Provisions for uninterrupted supply of quality raw materials to manufacturers	Business associations, GO
Business development	• Lack of uninterrupted supply of electricity	• Provisions for preferential treatment for supply of electricity to agri-machinery manufacturers	PDB, PBS, Ministry of Energy
	• Lack of space and infrastructural facilities for agricultural machinery manufacturers • Lack of scope for export in SAARC and developing countries	• Establishment of 'Agricultural-machinery Production Zones' in Bogra and Jessore • Provisions for duty free access to SAARC and developing countries, and formal trading of agri-machinery at border markets (hats) with India	GO (Ministry of Industries, foreign affairs), Business associations, Development partners
Policy advocacy	• Inadequate working capital and finance for capital machinery	• Provisions for easy access to soft and flexible long and mid-term credit facilities	Public and private sector banks, GO policy support
	• Lack of appropriate policies and regulations on mechanisation, import of capital machinery and multiple VAT on imported raw materials	• Provisions for appropriate policies and regulations on mechanisation, preferential treatment on capital machinery import and multiple VAT on imported raw materials	Business associations

Potential Centres for Agricultural Machinery and Spare Parts Manufacturing

Light engineering was the key for many developing nations for acquiring skill and technical knowledge for manufacturing endeavour. The sub-sector begins with the light engineering production activities and eventually ends up with heavy industry. Japan, China, South Korea are the examples. Once, Dholaikhal and Nowabpur of Dhaka were the main production and marketing centres of agricultural machinery and spare parts along with other light engineering production activities in the country. However, because of high concentration of businesses in these areas, agricultural machinery and spare parts production become expensive and gradually shifted to other potential districts of the country such as Bogra, Jessore, Sylhet etc. Among these potential areas, Bogra emerged as the most potential centre of agricultural machinery and spare parts production.

Bogra is the key business centre in the North Bengal because of its central location and well-established road communication network with the northern districts of Bangladesh. After the construction of Jamuna multipurpose bridge, road communication with the capital Dhaka through Bogra becomes easier for these districts. Eventually, Bogra has emerged as the business capital of North Bengal. The Bangladesh railway regional workshop at Syedpur contributed much in producing skill mechanics and technicians in this region. After the decline of this workshop, these skilled personnel started establishing private sector repair and maintenance workshops in the northern region of the country, especially, in Bogra and later on started production of agricultural machinery and spare parts, as there was a demand for these services in this region.

On the other hand, after independence, Jessore became the largest business centre of spare parts of Indian built automotive vehicles and its repair and maintenance. Later, local maintenance workshops turn into production units for spare parts of engines and agricultural machines.

Recently, the government of Bangladesh has been encouraging specialised zones for specific products. This would increase the productivity of the industries and quality of product through creating skilled work force for fulfilling the domestic demand as well creating potential for export. At present, Bogra is producing major share of agricultural machinery, small engine and machinery spares in the country and Jessore emerged as second largest producer of such products. Although, major shift has taken place from

Dholaikhal of Dhaka to Bogra and Jessore districts for the production of agricultural machinery and spare parts, the services related to production, such as quality test of products, heat treatment facility and metallurgical test are still not available in these districts. For sustainability, this sub-sector needs preferential treatment from the government. At this end, declaration of Bogra and Jessore districts as the centres of agricultural machinery and spare parts manufacturing followed by creation of at least one "Agricultural-machinery Production Zone (APZ)" in each districts is an urgent need. Provisions for infrastructural facilities, such as gas, electricity, testing of products, road, sanitation, water supply etc. are also to be made available in these APZs. The APZs must provide spaces for shifting of the existing production units from town centres and potential new production units. The shifting of the existing production units from the town centres may potentially reduce the environmental pollution. In Bogra, the potential area for the APZ may be the land acquired by the government for the establishment of heavy industrial zone near the Shahid Ziaur Rahman medical college.

Conclusions

Based on the discussion, the present status of agricultural machinery manufacturing in Bangladesh the following conclusions are made:

- Agricultural machinery manufacturing sub-sector is still considered as non-formal sector, however, in the backdrop of labour shortage at peak harvesting and planting seasons and increasing cropping intensity, the demand of agricultural machinery in field operation and postharvest processing of crop is increasing rapidly. The expanding market trend of agricultural machinery and spare parts in the country validates that premise. Apart from import of tractor, power tiller, diesel engines, motors, reapers, combine harvesters etc., a number of agricultural machinery such as centrifugal pump, open & closed drum threshers, maize sheller, weeder, sprayers, etc. and spare parts are being manufactured in the country. The quality of some locally manufactured machinery and spare parts are good and cheaper in price as compared to imported machines and spare parts and there is good market potential in the country. However, the production process in foundries and manufacturing workshops are not standardised and the quality of the products in subsequent batches cannot be maintained. To improve the situation, more investment is needed for capital machinery and capacity building of the working force in these industries and workshops. Therefore, investment friendly policies and strategies are to be adopted for further improvement of this sub-sector.

- The common supply chain of agricultural machinery in Bangladesh maintains three core channels, namely imported agricultural machinery, diesel engine, spare parts and raw materials channel; local agricultural machinery production channel and local spare parts production channel. The imported agricultural machinery, diesel engine, spare parts and raw materials channel is dominated by few importers and have dominant role over foundry and small manufacturing units. There is a strong belief that there is syndicate among the raw materials importers for which price fixation and supply of raw materials are beyond the control of the foundries and manufacturing workshops. The local agricultural machinery and spare parts production channels are taking its formal shape; still the channels have few intermediaries and informal dealerships at district levels are growing. Formal market chains need to be established not only to enhance the internal market of agricultural machinery and spare parts but also to extend the export market to neighbouring countries like seven-sisters of India, Nepal and Bhutan.
- Despite significant growth of few agricultural machineries and spare parts production, the sub-sector is facing numerous constraints. The sub-sector is lacking skill related to iron alloy, brass casting, heat treatment, etc. along with skills related to use of modern capital machinery for quality products and standardised production processes. Some of these are beyond the financial and management capacities of the small manufacturing workshops. Common facilities at commercial agricultural machinery production hubs would be pragmatic solutions for small manufacturing units.
- Most of the agricultural machinery manufacturing units are very small in size and located out of the major industrial zones, even no priority is given to these units at the BSCIC industrial areas at districts level. To ensure infrastructural facilities conducive to industrial production these production units should be relocated to specialised zone that can be established as Agricultural-machinery Production Zone (APZ) in major agricultural machinery production centres in the country.
- The foundries and centres of agricultural machinery and spare parts production workshops do not have proper quality control and research and development (R&D) facilities that lead to manufacturing of quality compromised products. For further development of these production units, R&D facilities must be developed within the units and provisions for common quality control and R&D facilities in major agricultural machinery production zones.
- Research and development for innovation and adaptation of agricultural machinery and technologies in the country is still unorganised and investment is inadequate. Therefore, flow of appropriate technologies, machines and related

skill and knowledge to the production units is inadequate. Establishment of institutional capacity, such as Central Institute of Agricultural Engineering (CIAE) and "National Standardisation Institute" are proposed for achieving a desired growth of this sub-sector.

- In the National agricultural policy, only small section is delegated to agricultural mechanisation that merely reflects the vision of mechanised agriculture in the country. A comprehensive agricultural mechanisation policy formulation is urgently needed for the desired growth of agricultural machinery and spare parts production and mechanisation of crop farming and processing of crops.
- The agricultural machinery sub-sector in the country is mainly driven by private sector initiative. The sub-sector needs major investment to harness its full potential to grow. At this end, this sub-sector needs recognition as formal industrial sector and access to credit and other financial and non-financial benefits similar to those in formal industrial sector should be reduced.

Recommendations

Based on the above discussion the following priority recommendations are made:

- Bogra and Jessore can be declared as "Agricultural Machinery Districts" to ensure infrastructural facilities, such as non-interrupted supply of electricity, gas, water etc. for agricultural machinery and spare parts production units;
- Establishment of "Agricultural Machinery Production Zones (APZ)" on the outskirts of Bogra and Jessore towns can be considered to accommodate existing and potential agricultural machinery industries and workshops;
- Establishment of 'Common Facility Centre' at each APZ can be considered to facilitate quality services related to heat treatment, material testing, test and standardisation, advisory services etc., with public, private and development partners initiative;
- Provisions should be made for duty free access to SAARC and developing countries, and formal trading of agricultural machinery at border markets (*hats*) through bilateral negotiations with India;
- Establishment of a "Central Institute of Agricultural Engineering (CIAE)" is recommended for continuation of innovation through R&D with support from government and development partners;
- Formulation and updating of National Agricultural Mechanisation Policy is needed;

- Establishment of National Standardisation Institute for agricultural machinery and spare parts can be thought of;
- Modernisation of local foundries through collaboration and experience sharing activities among SAARC and industrialised countries;
- Strengthening capacity of agricultural machinery entrepreneurs through transfer of proto-type machines and technologies among SAARC and industrialised countries should be promoted;
- Access to soft and flexible long and mid-term credit facilities for capital machinery and working capital needs to be considered;
- Policy options should be considered for removal of multiple VAT on imported raw materials and strengthen rules and regulations against illegal hoarding of raw materials for the growth and development of agricultural machinery sub-sector;
- Policy options should be rationalised for zero tariff/nominal tariff on modern capital machinery import for agricultural machinery sub-sector;
- BBS data base should include agricultural machinery sub-sector r; and
- Strengthening capacity of Foundry Owners' Association of Bangladesh (FOAB), Bangladesh Shilpa Malik Samity (BSMS) and Bangladesh Agricultural Machinery Manufacturers Association (BAMMA) should be strenghthened to safeguard the interest of the sub-sector.

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Chapter 8

Research and Extension in Farm Power Issues (REFPI) Project: Findings and Impacts

A.T.M. Ziauddin, R. I. Sarker and Gerard Hendriksen

Background

Bangladesh's accomplishments in transforming its agricultural sector into one of the most productive farm economics in South Asia is a major development success story. Once racked by famine and dependent on food imports, the country is now essentially self-sufficient in rice, is emerging as a significant exporter of high-value agricultural products and enjoys the second highest percentage growth in per capita income in South Asia. Its success is largely a story of close cooperation between the Government of Bangladesh, the well developed NGOs, the country's people, and foreign aid agencies.

Bangladesh is situated on a deltaic plain with a system of meandering rivers subject to annual flooding, and a small hilly region in east and south-east. The country has an area of 147,610 square kilometers including 13,830 square kilometers of water bodies. The current population is about 160 million and with a very high density of 1100 people/km^2. Bangladesh is an agricultural country whose main farm produces are rice, jute, potato, vegetables, fish, and poultry. Over four fifths of farms belong to marginal and small holding categories, while the average farm size is slightly over half a hectare, and this in effect conditions the farmers' choice of small- scale machines and equipment.

Evolution of Farm Power in Bangladesh

Farm power (human, animal or mechanical) for crop establishment, irrigation, harvesting, processing, and transport has become a critically important input for agricultural production. Irrigation is now practically fully mechanised as more than one million diesel and electric pumps bring ground and surface water to the fields. A survey report indicated that by 2000 about 65% of the land was tilled by power tillers. After a decade (2011), it was found that over 80% of the land was tilled with two-wheel power tillers and four-wheel tractors, while marginal farmers had access to these machines through private contract services. Custom hiring system in Bangladesh started with power tiller (2WT) and tractor (4WT) in early seventies and at present, it is gaining momentum. In the past, women spent many hours processing rice with the foot operated 'dekhi' but today rice hullers and mills have taken over this task.

Small diesel engines imported from China are the most common source of power for all agricultural activities. At the same time, these have also been widely adapted in river boats and more recently in motorised vans providing essential transport in the rural areas. A vibrant service sector comprising out of many small (and few larger) businesses has developed to import, distribute and maintain this equipment, while most tools, implements and spare parts are locally manufactured by thousands of workshops in all corners of the country.

Despite all these developments, manual labour remains the highest input cost in rice production in the country and is in short supply during critical periods as it is still essential for transplanting, weeding, harvesting, threshing, drying and many other farm activities. No doubt Bangladeshi farmers and rural entrepreneurs are keen to further mechanise some of these operations to reduce costs and increase timeline. Research and extension was required to support this process of mechanisation and for better understanding of the impact, this might have on the livelihoods of the rural poor, such as marginal farmers, agricultural labourers, and rural artisans, both male and female.

Research and Extension in Farm Power Issues (REFPI) Project

The REFPI Project started functioning in early 2000 in the Department of Farm Power and Machinery (DFPM) of Bangladesh Agricultural University, Mymensingh (REFPI, 2003). The Department for International Development (DFID) of UK provided financial and technical assistance not only to the DFPM but through a competitive research fund, but also to other GO –NGO institutions that were involved in research and extension on farm power issues. The implementation period was from April 2000 to December 2003 and the project operated in many corners of the country.

The long-term goal of the REFPI project was to make a positive contribution towards improved livelihoods of the rural poor through facilitating increased access to more effective and efficient farm power and machineries used by small farms and rural systems in Bangladesh.

It intended to reach this goal through strengthening of the capacities of government, NGO, and private sector institutions to carry out appropriate research and extension work on farm power and machinery issues that were relevant for the rural poor (marginal and landless farmers, rural traders, artisans, and labourers, both male and female). The impacts of these activities were not likely to be measurable during the project duration but were expected to take effect well after completion of the implementation period. In the medium term, the project made a significant contribution towards institutional development through a more capable Department of Farm Power and Machinery (DFPM) and Agricultural Engineering and Technology Faculty at the Bangladesh Agricultural University (BAU) and improved contacts between the BAU and other research and extension organisations (GO/NGO and private) in the country resulting in a more efficient use of farm power and machineries through the exchange of knowledge and expertise.

REFPI followed the principles set out in the Sustainable Livelihoods Approach (SLA) adopted by DFID and many other donor agencies to guide rural development programmes. REFPI put SLA in practice through:

a) Participatory research methodologies by stimulating project partners to engage with the various stakeholders, such as equipment manufacturers, suppliers, small rural traders, marginal farmers, and labourers.

b) Collaborative implementation of the research and extension projects through meaningful partnerships between GO, NGO, and private sector institutions.

c) Strengthening capacity of BAU and other partner organisations to sustain RD & E work through provision of institutional training and technical guidance.

d) Networking between national and international organisations that are contributing to an effective farm power sector through contacts, meetings, and exchange visits.

Implementation of the Project

The DFPM of the BAU was the leading partner in this project and REFPI's offices were located within the University Campus. Two senior staff members of the Department joined the project as Project and Research Coordinator, respectively, while DFID provided a Technical Advisor, support staff, an operating budget for the project and grant funding for the sub projects.

A Project Advisory Committee (PAC) was composed of expert persons from different organisations and professional background with an interest in the project's objectives. The PAC met 2-3 times per year to advise the project management in determining priorities for Research, Development & Extension (RD & E) sub-projects and for the reviewing of the research sub-projects selected through an anonymous evaluation process. The PAC also assisted the project in maintaining linkages with other institutions.

The total REFPI project funds were £1.6 million out of which £0.6 million were earmarked for research grants. The RD & E funds were equally available to the BAU as well as other government research organisations, NGOs, and private sectors. Research grants were awarded on a competitive basis through a two-stage selection process using concept notes and full proposals.

Guidelines and training for preparing proposals were provided by REFPI to meet the following criteria:

1) Clear relationship to the use of farm power for cultivation, irrigation, harvesting, processing or transport of agricultural products by small farmers, landless or other resources poor groups;
2) The proposals for the research should be demand led and implemented through a participatory process;
3) Proven or realistic pathways for dissemination of the results of the research are available and an integral part of the RD & E proposal;
4) Means of measuring the uptake and impact of the project activities have been identified.

Priorities for RD & E were based on a number of participatory farmer's need assessments carried out during the first year of the project. These and consultation with PAC members had resulted in the following RD & E research themes.

1) Many projects (more than number 15) had an element of adaptive machinery development and extension, while food processing was also well represented with eight projects. Others were on gender specific extension, small irrigation development and pure extension. A few projects were dealing with the health, safety and working environment of agricultural workers.
2) Project budgets varied from £5,000 to £75,000 and had a duration from 3-18 months depending on the nature of the work.

3) All projects had an element of extension for 3 to 12 months and were expected to contribute to uptake of the RD & E outcomes

By 2002 REFPI supported nearly 40 RD & E projects covering a wide variety of subjects (Table 1) and partners (Figure 1). The projects locations ranged from Dinajpur in the North West to Cox's Bazaar in the South East but with a concentration around Mymensingh where BAU traditionally has a strong network.

The RD & E Selection and Implementation Process

The following steps were followed to conduct RD & E activities of the project:

1. Setting of research criteria and priorities through a participatory process and in consultation with the Project Advisory Committee;
2. A total of three calls for sub-project proposals were issued over the project duration of three years;
3. An anonymous process involving REFPI management and external evaluators in the final decision making process on subproject proposals;

Impact evaluations during implementation and after termination of the sub-projects was carried out by REFPI management and by external evaluators.

Contribution of the REFPI Project

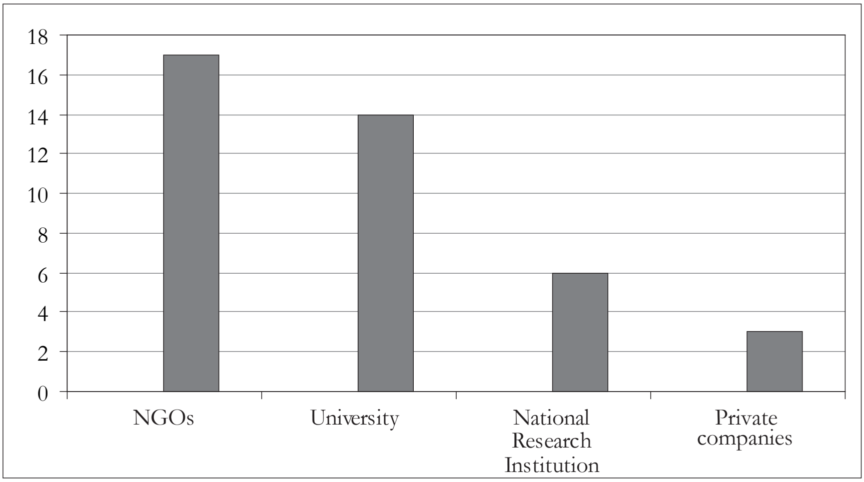
Rural life in Bangladesh is changing fast and access to energy including farm power is playing a key role in this transformation. A vibrant sector has developed to service the mechanisation process. Businessmen import equipment from abroad (mainly China), many metal workshops in Bogra and other towns manufacture spare parts and tools, and village-level craftsmen carry out repairs and maintenance of the hundreds of thousands of engines, water pumps, power tillers, simple transport and other farm equipment. The number of small shops in villages has increased substantially, as has petty trading in villages and *bazars*. We are witnessing the rapid development of rural industry and an explosive growth of the rural transport sector improving access to markets. Rural people are also taking advantage of these changes to diversify their livelihoods. REFPI has virtually acted as a catalytic agent in creating momentum of alleviating poverty, working in diversified areas of agricultural mechanisation through GO, NGO, and private institutions in a collaborative manner. An evaluation of the project is provided in Brown and Huda (2003).

Access to technology and sources of power are crucial to the poor. This is believed from the fact that poverty levels are significantly lower in countries that have shown high adoption rates for new technologies. But, all too often, the poor did not have access to power or new technologies. The Research and Extension on Farm Power Issues project (REFPI) aimed to address this inequality. It set out to develop and test approaches for delivering appropriate rural power technologies and necessary extension information to poor rural households.

Table 1
Classification of RD & E Projects by Subject

Subject Area	Number of Sub-projects
Equipments (threshers, reaper, spreader, potato, drying, briquette)	13
Food processing technologies	9
Gender targeted equipment	8
Livelihoods, gender and health studies	7
Irrigation systems and equipment	4
Enterprise development	4
Extension packages and field work	3

Figure 1
Number of RD & E Sub-Projects by Lead Institution



Key Outputs of REFPI Project

The following were the key outputs of the project:

1. Farm power research and extension needs for small farm systems were identified;
2. Effective research and extension system to address identified farm power needs was established;
3. Effective partnerships operating with and between relevant institutions on research, extension and service provision was initiated;
4. Enhanced Bangladesh Agricultural University capacity to carry out teaching, research and extension on farm power issues affecting the rural poor; and
5. Farm power issues were presented to relevant professional organisations and policy makers.

Impact of REFPI Project Beyond 2003

The impacts of REFPI project, especially strengthening agricultural mechanisation in Bangladesh were very significant. The following points were recognised by all concerned:

1) Innovations/development/manufacturing capability of farm technologies like threshers, fertiliser distributors /spreaders, reapers, irrigation devices and food processing by some GO/NGO/Private partners of REFPI enhanced.
2) Partners of REFPI like GO (BARI & BRRI), NGO (Proshika, IDE, RDRS& PBKS) and Private Sectors (Uttaran, Mahbub Engg., Alim Engg., and Bhai Bhai Engg.) are continuing their efforts for manufacturing and meeting increasing demands for various technologies with enhanced capacity.
3) Rural livelihoods improved due to non-farm employment for instance in processing and mechanisation support services.
4) Mechanisation of small farms increased several folds and contributed to food security.
5) Development of cereal harvesters/ reapers continued for some time but slowed down due to introduction of combine harvester by the Department of Agricultural Extension (DAE) under a subsidy programme..

6) More private sectors came forward to manufacture improved and innovative farm machineries and accessories across the country.
7) Reduced drudgery of farm work for men and women and allowed extra time for household and family comfort.

The achievements of REFPI went beyond establishing a "new way of working". Evidence is emerging that this new way of working has tangible impacts on the livelihoods of the poor. Among the most impressive and unexpected were those related to increasing poor people's access to farm power, and information on farm power.

Case Study 1: Farm Implements and Livelihood Impact on Women in Lalmonirhat District

RDRS is a large national NGO, which works with a local NGO in north western Bangladesh to develop and promote simple farm implements for women. Skill development and gender awareness training for men and women had been key parts of the programme. RDRS had tested a range of implements which have met with varying degrees of acceptance among women. For example, women did not take the seed and fertiliser distributor whereas other technologies, such as wet and dry land weeders proved more popular. The programme has created a demand for tools within the community, which local blacksmiths are now making to satisfy rural community. Benefits of adoption included reduced drudgery and time saving for women, development of skilled and more productive labour. In fact, the tools helped to empower women. There was also demand within the community for more sophisticated and expensive machinery and implements – providing RDRS with new challenges.

Case Study 2: A Locally Developed Power Thresher and Livelihood Impact on Farmers' Health and Drudgery

GRAMUS, a local NGO in Mymensingh has introduced a paddy thresher locally developed by a national GO research institution on cost sharing basis through a sub-project of REFPI. Men and women equally liked the technology as it has provided a good number of benefits to them, such as decreased working hours and drudgery by 80%; increased income as grain quality improved and grain losses decreased (Figure 2). It was interesting to note that the farmers were better off and were free from stomach ache as they were consuming quality grain today. They complained of stomach ache when they could not thresh their harvested grain within a day or two. As a result, the wet grain started deteriorating and losing quality. They had to consume this low quality grain as it had low market price and suffered stomach ache. This is a clear example how mechanisation has improved the livelihood of rural people.

Figure 2
Women are Using a Power Thresher– A Popular Device in Rural Bangladesh

Case Study 3 : Agro-Processing as an Entry Point for Improving livelihoods

A factory, processing locally available fruits, such as pineapple and jack fruit was established in Madhupur by BAU and a local NGO, Mouchas Unnayan Sangstha (MUS). A memorandum of understanding was signed between REFPI, the BAU researcher and MUS. The project provided capital for essential equipment, the researchers provided technical support on food processing skills and MUS was responsible for the supply of building and services and the overall management of the project. Twelve local women are now employed in the factory and products are sold as far away as Dhaka. This project has demonstrated what is possible and has grounded in reality the idea of local agro- processing, which is much talked about in policy circles. The business seems to be sustainable and is not dependent on continuing government sponsorship, buys its raw materials locally, has generated employment for women, has good food safety standards, produces high quality goods and is connected to rural and urban markets.

Case Study 4: Dynamism of Private Sector: Transformation from Metal Fabricator to Agricultural Machinery Manufacturer

Mahabub, a man in his mid-forties was a metal worker who used to fabricate grills and steel almirah. He was fascinated when a relative – a faculty member of BARI - demonstrated the use of a specially designed plough to the farmers. Mahabub came away with the idea of manufacturing agricultural implements. He also realised the importance of creating demand among farmers for farm implements and the need for capital to manufacture them. He saw REFPI's advertisement in the newspaper and prepared a concept note. REFPI suggested that he might link up with the Intermediate Technology Development Group (ITDG), an international NGO. Initially, he had some problems working with ITDG, which wanted him to make spare parts. Mahabub, however, was keen to manufacture agricultural implements. Through negotiation and interaction, they settled on a compromise: Mahabub would receive training from BAU under REFPI to manufacture implements and he would also train the local blacksmiths/manufacturers to make parts. As part of this scheme, he visited 8-10 districts to train local metal workers. This collaboration helped Mahabub to expand markets for his products as he was able to establish links with BAU and NGOs, such as Proshika. Mahabub eventually became an enlisted manufacturer of BARI and BRRI.

Emerging Lessons

The REFPI project has accumulated three and a half years of experience. Some key lessons have emerged about how to make project work relevant to poor peoples' livelihoods

Lesson 1: Adopt a Practical Interpretation of Sustainable Livelihood Approach

REFPI adopted a broad definition of farm power, embracing all aspects of technology in rural development, covering the three power sources (human, animal, and mechanical), the way the power was applied through tools, implements and machines and the effects on the well-being of humans and the environment. The message to all those involved in REFPI was clear: poor peoples' livelihoods were the focus of the project. It took a practical approach by:

- Developing a short-hand project title to remind people of its focus: Rural Livelihoods and Farm Power;

- Adopting a demand-driven participatory approach to identify poor peoples' needs and priorities;
- Mainstreaming gender and environment issues;
- Adopting a multidisciplinary and multi stakeholder approach;
- Including institutions that interface with the poor and affect their daily lives;
- Focusing interventions locally, where change can make an immediate impact on livelihoods; selecting RD & E proposals that had a realistic chance of delivering livelihood impacts within the project's timeframe;
- Proving close support and guidance during the implementation of the RD & E projects; and
- Actively promote exchange of knowledge and ideas among the key stakeholders

Lesson 2: Focus on Development Processes, not on Target Groups

REFPI cut through the difficulties of delineating target groups and debating how they might be reached. Instead, it focused on processes of poverty alleviation. It set out to identify how RD & E on farm power issues can strengthen development processes, which in turn brought positive livelihood benefits to the poor. These include improving productivity through timeliness of agricultural operations, employment generation, development of new income-earning opportunities, improving access to services, skill development, capacity building of local institutions and improvements in working environments (tackling health and safety issues). At all stages, REFPI stressed the need to be explicit about how these processes both directly and indirectly impacted on the livelihoods of the poor. The challenge was to identify how RD&E on farm power issues can strengthen development processes.

Lesson 3: Competitive Grant Systems (CGS) Can Deliver Appropriate Technologies to the Poor

The success of the REFPI CGS rests on the establishment of rules and procedures that encourage demand-led, participatory and livelihood-focused research. Many of these built on best practice in CGS, such as:

- Defining the RD & E agenda by identifying poor peoples' needs through a participatory process. This was different from the normal way of doing things – where the ideas of the researcher – rather than the needs of the end user - drives the research;

- Awarding funds on the basis of merit, which provided an incentive for improving the quality of research from organisations that were subject to minimal performance incentives or sanctions;
- Funding transparency and accountability through an open bidding process by advertising in the national press; use open criteria to access merit of proposals; adopt a thorough screening process and give feedback on why the proposals of unsuccessful bidders were rejected; adopt systematic and uniform monitoring; adopt appropriate and stringent financial management and develop clear rules on ownership of assets from the project.

Lesson 4: Successful Partnership Goes Beyond Role Division

Partnership was a cornerstone of the REFPI project, which had promoted the message that, by itself, RD & E rarely reached the end users. The partnerships promoted through REFPI have bridged many gaps between technical and socio-economic disciplines; between commercial and development agencies: between researchers and farmers. This has often challenged the boundaries and 'comfort zones' of members of the various institutions e.g. GO and NGO engagement with the private sector and BAU involvement with the informal sector – the myriad small unregulated metal workers and blacksmiths.

Partnerships often go beyond the expected "role division", for example, universities researching and GO and NGOs doing the extension. Institutions were increasingly aware of the potential and value of partners' knowledge, expertise and networks.

Lesson 5: Use the Dynamism of the Private Sector to Reach the Poor

REFPI has shown how to work successfully with the private sector. In the absence of government extension capacity in engineering, the wide network of local blacksmiths, machine workshops and entrepreneurs provided the most likely means of scaling up the dissemination of farm power technologies and information. REFPI has seized this opportunity to build skills and capacity in this sector in areas of management, accounting and technical competence. REFPI has demonstrated that the informal private sector is often the most relevant institution in terms of farm power for rural people – generating employment, providing services and as a source of technologies for farmers.

Tapping into and stimulating the extensive network of blacksmiths and local entrepreneurs at a level that had an impact on livelihoods - considered another key achievement of the project.

Conclusions

REFPI was a highly appreciated project, its implementation succeeded through a combination of responsive and flexible management together with partnership and interest from a wide stakeholder group to identify, test, adapt and adopt appropriate technologies relevant to the improvement of livelihoods.

The key lesson that emerges is that the development and extension of farm power technology is an important entry point for improving livelihoods of the poor. Indeed, we might extrapolate further. If the poor are not given appropriate support to access farm power and technology, they are at risk of being further marginalised from development processes. REFPI has demonstrated what is possible; with the right systems and incentives in place, technology research and development can make a difference to poor peoples' livelihoods. However, it has achieved this on a small scale. Finally, the impact of REFPI at policy level cannot be ignored also. A proposal was prepared to form a separate institution called, Bangladesh Krishi Projukti Foundation, with a view to following the concept of REFPI to develop an alternative system of funding to improve the efficiency and effectiveness of the prevailing research system through generation, evaluation and dissemination of need-based technologies.

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Chapter 9

Agricultural Mechanisation in the State of West Bengal, India

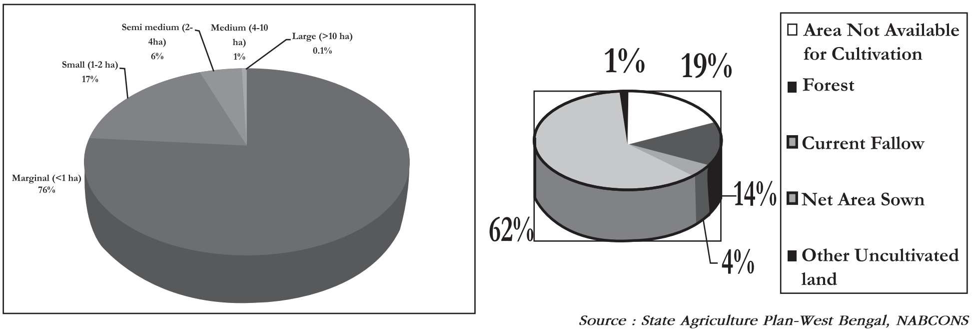
V. K. Tewari

Introduction

West Bengal has the third largest economy in India with the net state domestic production of Rs. 860 billion. Agriculture accounts for 27% of the State economy. About 75% of the population in West Bengal resides in rural areas. The farmers cultivate their ancestral lands mainly by family labour. The average cropping intensity is 182% in 18 agricultural districts of West Bengal, which is 33.8% higher than the country's average. About 47.6% labourers are engaged in agriculture. The percentage of agricultural labour in rural population with land is 10.5% and without land is 13.3%. More than 70% land holdings in the State are less than one hectare. Only 7% holdings (IASRI, 2006) are greater than 2 ha. The average size of land holding in the State is 0.8 ha (Figure 1).

Figure 1

Status of Land Holdings and Utilisation of Land in West Bengal

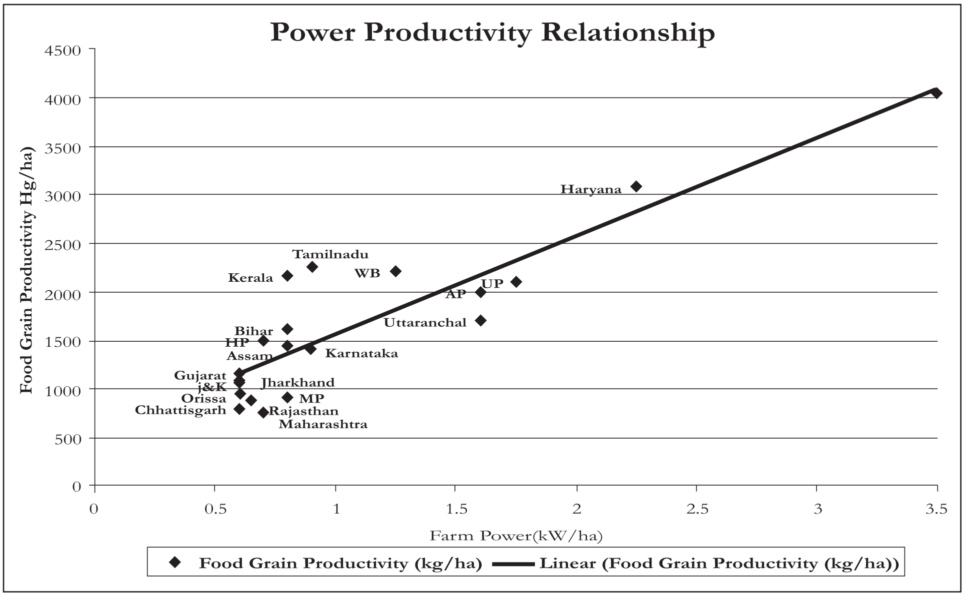


Source : State Agriculture Plan-West Bengal, NABCONS

Farm mechanisation[2] may be viewed as package of technology to ensure timely field operations, increased productivity, reduced crop losses and improved quality of grain or product (Barua and Bora, 2008). Diverse farm mechanisation scenario prevails in the country due to size of farm holdings and socio-economic disparities. Farm machines have not only increased the mechanical advantage, but also helped reduce drudgery while performing the different agricultural operations. The contributions of agricultural mechanisation (Chauhan,et al., 2006) in various stages of crop production could be viewed as saving in seeds (15-20%), saving in fertilisers (15-20%), saving in time (20-30%), reduction in labour (20-30%), increasing in cropping intensity (5-20%) and higher productivity (10-15%).

Figure 2

Farm Power and Productivity Relationship in Different States of India



Further, mechanisation does reduce the physical demand on the farm workers. In view of this, popularisation and implementation of farm machinery for various farming activities is the need of the hour for increased productivity and sustainability of the State's agriculture. The general information available from Directorate of Agriculture , Government of West Bengal indicates that West Bengal is the leading producer of paddy and second largest producer of potato

(30% of country's production) in the country. Farm power availability in West Bengal is 1.25 kW/ha, which is less than average farm power available on Indian farms (1.50 kW/ha) (Singh, 2006). There is a direct relationship between farm power availability and farm productivity as indicated in Figure 2.

Mechanisation Status of West Bengal Farms

Based on socio-economic parameters, it is observed that 41% cultivators fall under low income class; 52% cultivators fall under low middle class; about 7% cultivators fall under high middle class. The implements used by the cultivators for performing various agricultural operations are country (*deshi)* ploughs, Bose ploughs, levellers, long handle spades, row markers, and *Khurpis.* Low income, less land holding, lack of proper infrastructure and inadequate facilities of repair and maintenance for different types of machinery/implements have forced a poor mechanisation status to the State of West Bengal. Details of different farm machinery and equipment widely used in West Bengal, their field capacity, man-hour/ha, and unit cost of operation (Rs./ha) are shown in Table 1.

Table 1

Implements and Tools Used for Crop Production in West Bengal

Tool/ Implements	**Field Capacity (ha/h)**	**Man-hour/ha**	**Unit Cost of Operation (Rs./ha)**
Bose plough	0.035 - 0.040	25 - 30	820
Khurpi	0.004	250 - 300	2900 - 3245
Row marker	0.06 - 0.19	17 - 20	260
Spade	0.05	128 - 160	1488 - 1860
Sickle	0.03	210 - 240	2325 – 2790
Tractor intensity in West Bengal			4.61 per 1000 ha
Power tiller intensity in West Bengal			5.12 per 1000 ha

Package of Machinery for Higher Production

Based on the status of mechanisation followed by the farmers, it appears that there is a mechanisation gap in puddling, sowing/transplanting of paddy, weeding and harvesting of the major crop (paddy) in the State. In the case of wheat, implements are required for sowing, harvesting and threshing. Same is the case with mustard, groundnut, and jute. In the case of potato cultivation, automatic potato planter and potato digger elevator are required to increase the benefit- cost ratio. Examining the issue, it could be arrived at a complete package of machinery required for various crops for better production and productivity. Such a list for paddy, wheat, potato, jute, mustard, and groundnut cultivation is given in Table 2 and the view of these machines is shown in Figure 3a & 3b.

Table 2

Suggested Package of Implements and Machinery for Various Crops in West Bengal

Tillage Implement and Machinery		**Sowing and Planting**	**Plant Protection Equipment**		**Harvesting and Threshing**
Primary Tillage	**Seed Bed Preparation**		**Weeding**	**Spraying**	
Paddy					
M B Plough, Disk plough, Cultivator	IIT Puddler, Hydrotiller, Power tiller, Rotavator, Tractor drawn Puddler	Self propelled paddy Transplante r, Drum seeder	Cono weeder, Hand-hoe, Wetland weeder	Knapsack sprayer, Foot sprayer, Power sprayer	Vertical conveyor reaper, Reaper binder, Combine harvester, Axial flow paddy thresher

Use of the listed machinery would help in enhancing the production status of different crops. The field capacity and unit cost of operation of the implements and machinery to be used for different crops are given in Table 3.

Figure 3a
Improved Farm Machines


Trans planter


Cono weeder

Reaper


Paddy thresher

Zero till drill


Wheat thresher


Mini combine

Figure 3b
Improved Farm Machines

Potato planter

Potato digger


Raised bed planter


Ground nut digger


Ground nut stripper

Table 3

Improved Implement and Machinery with Field Capacity and Unit Cost of Operation

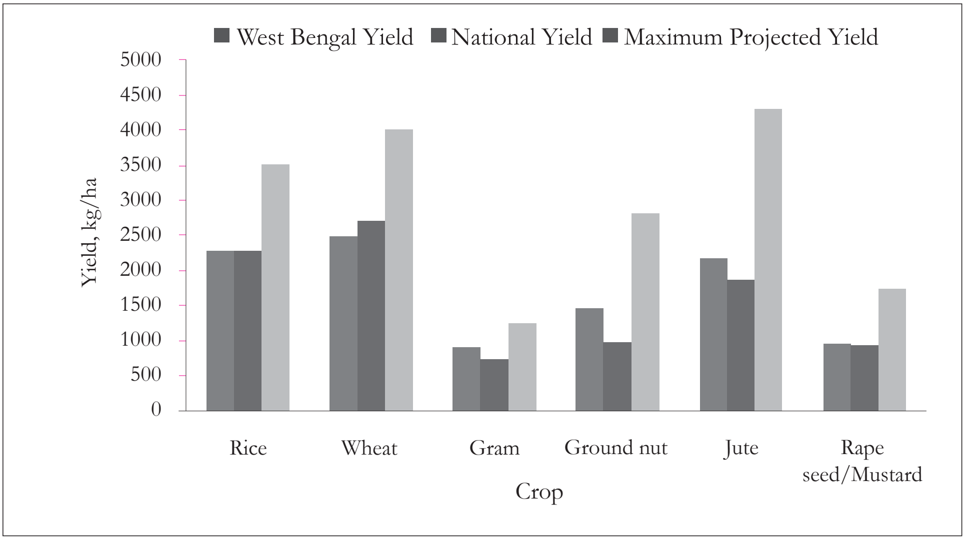
Improved Implements/Machinery	**Field Capacity (ha/ hr)**	**Man- hour/ Hectare**	**Unit Cost of Operation (per ha)**
IIT Puddler (Bullock drawn)	0.10 - 0.13	10 - 14	392
Hydro tiller	0.15 - 0.2	5 - 6	470
Drum seeder	0.125	16	320
Self- propelled paddy transplanter	0.15 - 0.18	27 - 35	1000
Zero till dill	0.4 - 0.5	4	700
Inclined plat planter	0.12 - 0.15	8 - 10	425
Cono weeder	0.025	30 - 35	390
Vertical conveyor reaper	0.20	5 - 6	240
Reaper cum binder	0.25 - 0.30	4	280
Mini combine	0.15 - 0.20	20 - 25	790
Axial flow paddy Thresher	0.2 - 0.3	20 - 25	600
Multi crop thresher	0.8 t/h	-	400

Source: Tewari (2008; 2010).

It is to be noted that introduction of machinery would definitely increase the present status of Mechanisation of crops for the State. When compared with national average for the current productivity and assumed productivity with the use of machinery (Tewari, 2008-2010; 2008), it could be seen that there is a large gap in the yield average (Figure 4).

Figure 4

Projected and Present Yield at National Level and West Bengal of Different Crops Using Mechanisation



There are considerable gaps between the actual and potential yields which have to be reduced by further boosting the productivity per unit area or per unit time. The scientists are trying to develop and promote technology for sustainable agriculture through conservation and efficient utilisation of natural resources keeping the limitations of land resources, biotic pressure on land, natural precipitation, availability of solar energy and social and economic diversity of the farmers. Extension and promotion of these critical technologies are essential to fulfill the future demand.

Mechanisation Model for Different Crops in West Bengal

The maximum productivity can be achieved through Mechanisation, better strategies for farm power, improved implements and machinery for all important crops including horticultural crops depending on the financial capability of the farmers for enhancing farm production. The Mechanisation model could be viewed in two different forms i.e., mechanisation for major crops and mechanisation for horticultural crops.

Mechanisation of major crops

- Paddy is the major crop grown in the State. At present, most of the operation is performed with manual or animal power. In order to increase productivity, intensity, and timeliness of operations and also to reduce human drudgery, improved implements and machinery like self propelled paddy transplanter, cono weeder, power weeder, vertical conveyer reaper and reaper binder should be introduced.
- The State ranks second in the production of potato in the country. It is an important crop not only for nutrition but also for the income of farmers. Equipment for all the operations of potato production is commercially available and should be selectively introduced for higher productivity. Animal-drawn and tractor drawn automatic potato planters, power weeders, potato diggers and graders need to be given priority for large scale adoption.
- The government plans to achieve self-sufficiency in wheat production. This will require additional area under wheat and more importantly Mechanisation of all critical input operations. Harrows, rotavators, zero till drill, threshers, and combine harvesters would be required on a large scale.
- West Bengal is one of the world's largest jute producing and processing region. Improved methods of cultivation increases jute fibre yield by 24% and reduce cost of production by 9% in farmer's field. Harrows, rotavators, jute seed drill and vertical conveyer reaper would be required on a large scale.
- Groundnut is the largest oilseed crop in India in terms of production. Lot of potential is there for increasing productivity through all the critical inputs. Raised bed planter, inclined plate planter for sowing of groundnut and groundnut digger cum shaker and thresher for harvesting and threshing operation would be the need of the hour.
- Mustard is important crop in some part of the State. Introduction of pneumatic planter for sowing and vertical conveyer reaper for timely harvesting is essential. Introduction of these would reduce the cost of production significantly.

Mechanisation of horticultural crops

The State of West Bengal is a major producer of all kinds of horticultural crops. However, the level of mechanisation in these crops is negligible. In order to compete for the quality and productivity, it is necessary to introduce appropriate tools and equipments, which are commercially available. Rotavators, precision seeders/planters, efficient sprayers, weeders, and diggers/harvesters are required for vegetable and fruit crops. For orchards, pit makers, pruning tools and air assisted sprayers for tall trees are essential. Some parts in the region, especially near big cities can be developed for introducing greenhouse technology for growing high quality vegetables and flowers for which good markets are available in these cities. In fact, climatic advantages in some parts of the region favour use of greenhouse technology for producing export-oriented flowers and vegetables.

Agricultural Mechanisation Strategy (AMS)

An AMS deals with manual, draft animal, and mechanical power, the utilisation of tools, implements, machinery, their supply and maintenance. The strategy may cover importing and domestic manufacture of tools, equipment and machinery, their repair and maintenance, relevant training and extension programmes through SHG and NGOs, custom hiring services and promotion of financing systems for the purchase of draft animals and machinery and power sources. The dominating philosophy for development today is that governments should provide the basic conditions which would encourage private individuals and organisations to take appropriate initiatives and make sound investments to contribute to national development objectives with minimal government interventions.

Role of custom hiring services

In West Bengal, more than 93% of operational land holdings are either marginal (<1 ha) or small (1-2 ha) in size. Investment capacity of majority of the farmers in these categories of land holding is poor. These farmers cannot spend on expensive farm power and machinery. However, they are making use of modern technology like combined harvester, tillage, sowing and planting machinery through custom hiring, through private entrepreneurs, self-help groups (SHG), NGO, or co-operatives. This will help increase the annual use of these equipment, thereby making farming economical. Thus, custom hiring of specialised farm equipment for replacement crops can greatly facilitate diversification of production of agriculture as well as to generate jobs for the unemployed youth in the villages.

Role of self help groups (SHG) and NGOs

Mechanisation is a costly affair for the farmers of West Bengal as the number of marginal and small farmers is large. In West Bengal, mechanisation can be implemented through the SHG and NGOs. They can be helpful in educating farmers about the new innovations in farm machines. They can also help in transferring the low cost technologies to farmers through their own system of financial funding. A well articulated self help group can reduce the resistance being put by the farm labourers and educate them about the new job opportunities that will come with the implementation of mechanisation.

Role of banks and other financial institutions

Farmers approach money lenders to meet their credit demands and pay exorbitant rate of interest. The nationalised banks come as a stimulant for adoption of farm mechanisation and establishment of agro- service centre through their provision of liberal credit loans. Loans are made available for the purchase of tractors, power tillers, diesel engine, reaper, new improved agricultural machinery and implement package depending on need. They also contribute to the network of custom hiring, servicing and sales through agro-service centres. Other state organisations like Land and Seed Development Corporation, West Bengal Marketing Federations, etc. also have come up in providing technical and financial help to promote the mechanisation activity.

Role of government and private organisations

Government, as a donor organisation increases funding for agricultural research and for supporting institutions relevant for small-scale farmers. They implement policy reforms that encourage private and public sector participation in economic activities in accordance with their comparative advantages. Government is focusing on addressing market failures, ensuring competitiveness and quality of support services, protecting the environment and common property resources and promoting balanced regional development. Private organisations are also adopting recommendations to develop micro credit programmes, extension services, education and marketing support for small- scale farmers, especially women, the less skilled and the disadvantaged. A cumulative effort of the State government and private organisations in implementing need based strategies to develop the farming sector through effective mechanisation of farms of West Bengal would be a convivial signal in achieving the projected production of different crops. This will help the farmers and thereby the State to become a significant contributor to the national economy.

Conclusions

It is true that farm mechanisation has shown good result in of raising the agricultural production and improving the standard of living of cultivators within very short period. But a number of arguments have been placed in the State of West Bengal, which could be listed as follows:

1. The poor economic condition of the farmers, fragmented land holding, poor rural transport facility coupled with inaccessible farm/field are some of the inherent constraints of the state in the path of farm mechanisation.
2. Lack of proper knowledge of the farmers about farm machines, their operation and maintenance remains a problem.
3. Lack of local manufacturing, repairing and replacement facilities, especially in remote rural areas is another hindrance in efficient small farm mechanisation.
4. The State of West Bengal has sufficient generating capacity of electric power, but its availability in rural sector is not adequate. Emphasis on rural electrification is necessary to give boost to agro-based rural industries so as to help these small entrepreneurs enhance farm outputs and hence income.
5. The existing level of available farm power is about 1.25 kW/ha, which is inadequate to enhance the cropping intensity and output of the farm sector. This level needs to be raised to 3.0 kW/ha by 2020 by introducing power sources like, power tiller, tractors (preferably by custom hiring), electric motors and engines.
6. Agrarian nature of the society loaded with acute socio-political problems hinders adaptation of machinery for agricultural production. But, agricultural development through appropriate farm mechanisation is essential, without which a rapid rise in production is not possible.

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Chapter 10

Mechanisation of Paddy Processing and Milling Practices in Bangladesh: Millers' and Consumers' Perceptions

W M H Jaim and Mahabub Hossain

Introduction

Cereals are the most important source of nutrients in Bangladesh accounting for 80% of all calories consumed (mostly from rice). Cereals also account for about 62.82% of protein, 86.23% of carbohydrate, 50.08% of iron and 12.35% of calcium (Jahan and Hossain, 1998). Except wheat, rice is the cheapest source of supply of calories and carbohydrate in Bangladesh. It is also one of the cheapest sources of protein and fat. However, a considerable portion of nutrient from rice is lost due to rice processing / milling as well as cooking practices in Bangladesh. Minimising a small amount of loss due to rice milling / processing and cooking practices can go a long way in meeting the deficiencies of some important micronutrients in Bangladesh as the per capita daily intake of rice in the rural areas is 441.61 grams (BBS, 2011).

Paddy processing includes parboiling (soaking and steaming), drying and milling in order to get milled rice. In some places, parboiling practices are not followed. They get milled rice by milling raw paddy. Milling is the final step in post-harvest processing of paddy. The types of rice mills and processing operations significantly affect the recovery and quality of rice.

Paddy processing and milling practices using different types of mills as well as perceptions of the millers and consumers about good quality of rice have important implications from nutritional point of view. Keeping this in mind, the specific objective of this paper is to investigate paddy processing and milling practices of rice and to explore perceptions of both millers and consumers to understand its impact from nutritional point of view.

Data Source

Both secondary and primary sources were used in this study. Secondary sources were used particularly in relation to technical aspects of paddy processing and rice milling activities, while for data from primary sources, two types of surveys were conducted among rice millers and rice consumers. In selecting millers and rice consumers from villages all over Bangladesh, this study followed the same methodology as was used in the nationwide study of "Impact of Green Revolution on Growth of Agricultural Income and Income Distribution System "conducted by the Bangladesh Institute of Development Studies (BIDS) in 1988. This study targeted to cover all the 64 districts of Bangladesh; however, ultimately 62 districts were covered as two districts in the Chittagong Hill Tracts were excluded due to problem of collecting data.

To select households for conducting the BIDS survey, at first, from each district one Thana / Upazila was selected randomly. Then from the selected Upazila, one Union was again selected randomly. Ultimately, one village adjacent to the Union was selected. Thus, 62 villages were selected for the study from which households were selected randomly for conducting the survey. Following the BIDS survey in 1988, repeat surveys considering the same households were conducted in the years of 2000-01 and 2004. The repeat surveys of the households were conducted in randomly selected 50% of the 62 districts. Thus, 31 districts were selected with 31 villages which were selected for earlier studies. These 31 villages were also selected for selecting rice millers and rice consumers' samples for the present study.

Three types of rice mills were found in the study areas; these were traditional rice mill, semi-automatic rice mill and mobile rice mill. From each village, one traditional rice mill was selected randomly where there were more than one mills. However, in the selected villages where there was no traditional mill, the adjacent mill of the neighbouring village where the villagers go for husking rice was selected. Thus, 30 traditional mills and one semi-automatic rice mill were selected. As the number of recently introduced mobile mills were much less than traditional rice mills, it was targeted to selected 15 mobile mills from the randomly selected 15 villages. One mobile rice mill was selected randomly from those villages where there was more than one mobile mill. Again, in selecting households for rice consumers' survey, the same households were selected which were considered for the repeat survey in 2004. Thus, 1007 households were selected for rice consumers' survey. The data for this study was collected during the period of December of 2005 to February of 2006 by a consulting firm. Socioconsult Ltd.

Rice Mill Categories

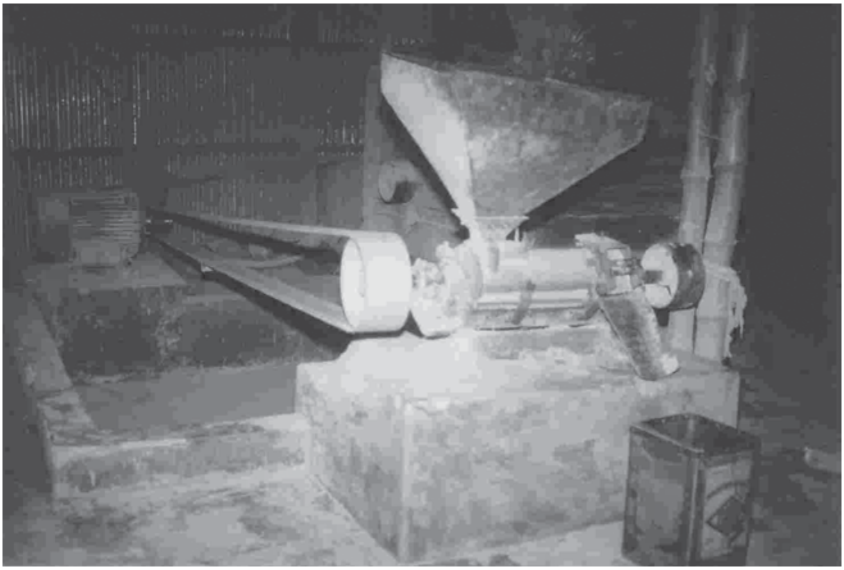
In earlier age in Bangladesh, *dheki* made by wooden plank was used to mill the paddy. At present, Engelberg system of hauling and milling has replaced the *dheki*. The Italian introduced this Engelberg system of milling in the 18th century. About 95% of milling is done by Engelberg system at present in Bangladesh. New systems of paddy milling and husking by rubber sheller as well as polishing by rubber polisher have been introduced in Bangladesh. This system of rice milling and polishing was at first introduced in Japan which produces better quality of rice than that of Engelberg system.

The classification of rice mills varied in different studies depending on coverage of various aspects in different studies. According to different methods of rice processing and milling practices, rice mills have been classified into following four categories:

Traditional Rice Mills

Traditional rice mills are those commercial rice mills which are operated at the village level using simple traditional technology and locally made devices.

Figure 1
Traditional Husking Rice Mill



Traditional mills usually do some polishing in addition to husking mostly by using two or more passes through huller or through a tandem of hullers to grind off some of the bran after husking. Paddy soaking in tanks, parboiling, drying the paddy in the sun on concrete floor and milling in rice mills are the functions performed in case of this type of mill. However, in some cases of small traditional rice mills, there are no parboiling and drying facilities. Hull and bran are separated manually in the case of traditional rice mills and the milling capacity is about 1 ton per hour. This, however, has reduced with the introduction of small sized traditional mills in recent years. According to methods of paddy processing and milling process, traditional rice mills can be again categorised into two types: i) husking rice mills (Figure 1), and ii) major rice mills (Figure 2).

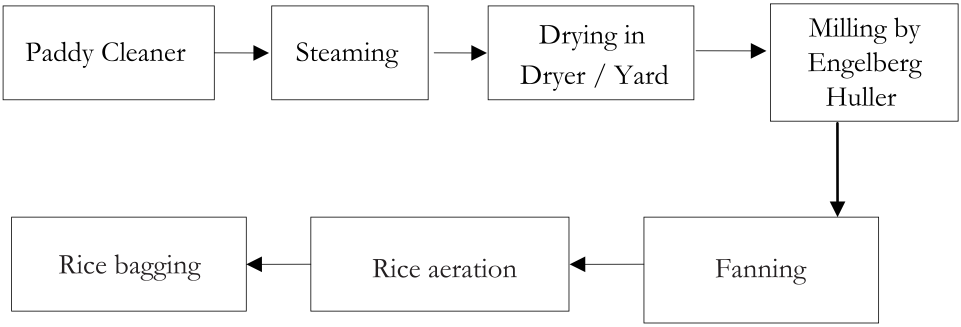
In the case of husking rice mills, milling operations are done for providing custom service to the farmers or petty businessmen. Other processing operations like parboiling and drying are done by the farmers themselves. These huller / husking rice mills are located at the village or market places and the farmers have to carry their own paddy to the mills.

Major rice mills do all the rice processing operations needed for parboiled rice. In addition to custom services, the millers procure paddy from local market, process paddy to produce parboiled rice and then sell it to local markets or distant markets or distant customers / businessmen. Traditional methods and tools are used for rice processing.

In most of the cases of medium sized major mills which process paddy for milling, the boiler is not standard. There is no system of measuring steam-pressure. This results in under steaming or over steaming which affects the quality of rice. Steaming consumes much time and drying on yard by sun is not uniform. In this type of mills, Engelberg huller produces more broken and under polished rice. It mixes bran and husk together. Rice produced in this system has less storage value and vulnerable to insect-organisms. This becomes off-coloured within a year. The 'Chimney' is not up to the standard height of 50 feet which causes environmental pollution (Ali, 2002).

In the case of major commercial rice mills, the boiler is standard. Artificial drying unit is available in some mills. There is a controlled system of steam pressure which results better consistency of rice. The hullering system is Engelberg, consistency of rice is more developed than the rice produced in the husking mill. In this case, the mills have neither paddy cleaner nor are rice grader and polishing the best (Ali, 2002).

Figure 2
Steps in Operations by Traditional Major Rice Mills

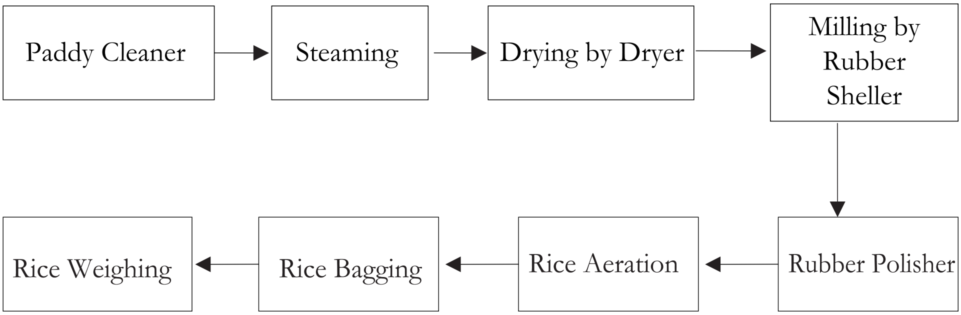


Source: Ali (2002)

Semi-automatic Rice Mills

Semi-automatic rice mills are those which perform the processing operations using either improved or modern boiler, dryer and milling devices (Figure 3). The operations consist of steaming the paddy before soaking, soaking the paddy in concrete tanks, parboiling by using standard steam broiler with a meter for measuring steam pressure and artificial drying. However, in some cases, parboiling and drying of paddy are done like traditional major mills. In the case of semi-automatic rice mills, milling and husking are done by using rubber sheller. Rubber polisher is also used for polishing rice. Hull and bran are separated mechanically and the capacity of these mills ranges between 1 and 2 tons per hour (Baqui *et al.*, 1994). Rice produced in semi-automatic rice mills is well-polished and less broken (Figure 6).

Figure 3
Steps in Operations by Semi-Auto Rice Mills

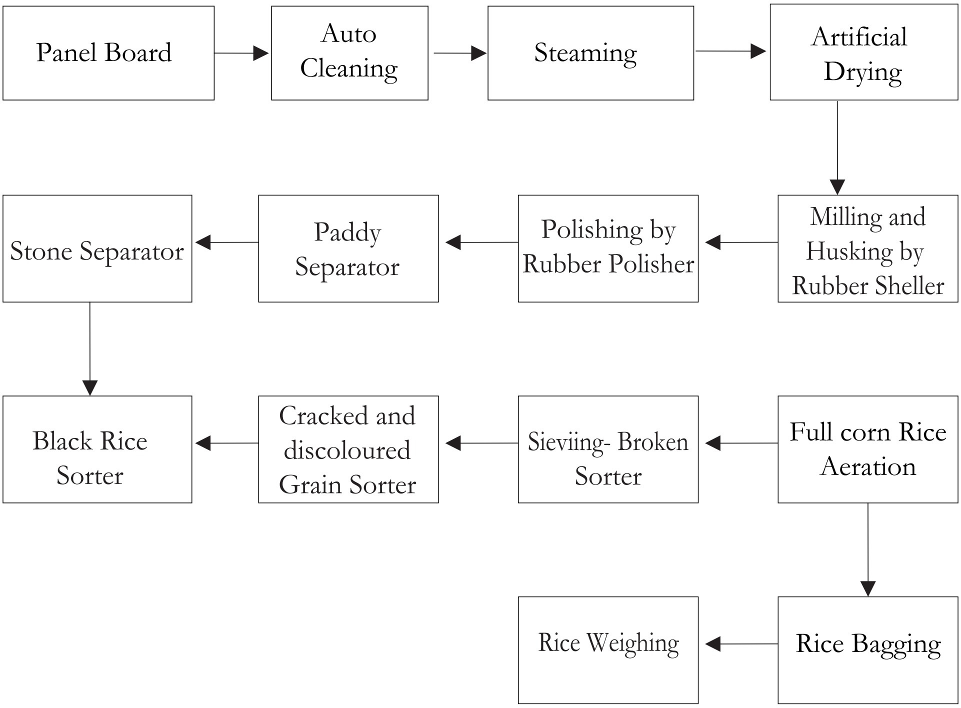


Source: Ali (2002)

Automatic Rice Mills

These mills use modern techniques for paddy processing and almost all operations, such as cleaning of paddy, soaking, parboiling, drying, dehusking, paddy separation, polishing, and cleaning are mechanised (Figure 4 and Figure 5). The paddy is pre-cleaned before soaking in water at high temperature and parboiled under pressure by steaming. Then paddy is dried in a dryer and husked by rubber roll huller. The unhusked paddy is separated from the brown rice by a paddy separator and is recycled back to the huller. Brown rice is polished by rubber polisher. Milled rice is graded according to head rice, large broken, small broken and process about 5 tons of paddy per hour (Baqui *et al.,* 1994). Automatic rice mills equipped with rubber roll huller in Bangladesh have been processing mostly locally available short grain (3-4 mm) aromatic rice as unparboiled condition.

Figure 4
Steps in Operations by Automatic Rice Mills



Source: Ali (2002)

Figure 5

Paddy Parboiling and Drying Units of Automatic Rice Mill

Mobile Rice Mills

The mobile mills, unlike traditional and semi-automatic/automatic rice mills do not have any fixed premises for its operation. So, it has no land cost as well as paddy parboiling and drying activities; the only activity is paddy husking using Engelberg huller. Normally engine of a tractor/power tiller or shallow tube well is used for rice husking with additional investment in purchasing accessories for rice milling purposes. The owner of the mobile rice mill moves from one place to another or in other words, from one house to another with the huller machine and provides paddy husking services to the farmers / customers in their own homestead areas. Technically, this is just like a small rice husking mill. The difference is, in the case of traditional husking mills, the huller is installed in milling rooms with good concrete foundation, while in the case of mobile mill it is moveable. Villagers, particularly the small farmers like mobile rice mills/huller because it provides home services which saves their time and cost of carrying paddy, especially small quantity of paddy to the mill premises. The milling capacity of mobile rice mill is about 0.30 - 0.40 tons of paddies per hour.

An earlier study by Farouk and Zama (2002) reports that about 95% of milling is done by Engel berg type steel huller in Bangladesh. Traditional rice mills of different capacities are available all over the country, although exact number of these mills is not known. The traditional *decoy* for rice dehiscing has gradually disappeared and mobile rice mills / hullers are gaining popularity in rural areas. The number of mobile rice mills may be a few thousands at present. Number of automatic rice mills as well as semi-automatic rice mills in Bangladesh is considerably lower compared to that of traditional rice mills.

Rice Processing and Milling Activities

Among different types of rice mills, traditional rice mill is dominant in milling operations in rural Bangladesh and according to milling operations, two types of traditional rice mills can be seen in rural areas: husking mills and major rice mills. It has already been mentioned that technically husking rice mills are like mobile rice mills, while the traditional major rice mills, in addition to rice husking, do other rice processing activities like parboiling, drying, etc. Therefore, in this section, technical aspects of rice processing activities by the traditional mills have been briefly discussed. However, since there was only one semi-automatic rice mill in the sample, this has been considered separately as a case study.

Rice Processing by Traditional Mills

Rice processing by traditional mills includes several steps like cleaning, parboiling, soaking, steaming, drying, milling, and separation of rice husk, head rice, broken rice and bran.

Cleaning of paddy

Cleaning of paddy before processing is an important step for production of good quality rice, but in general this step is ignored by most of the traditional millers as it is a labour consuming job. Cleaning, however, is partially done during soaking. But, cleaning of paddy during soaking is not adequate because the dusts penetrate into the grains in soaking resulting in poor quality rice.

Moreover, during soaking fine dust particles may stick to the grains and cause severe wear of milling machine. The presence of metallic substance, stone and dusts in the paddy cause rapid wear of huller machine parts (Farouk and Zaman, 2002).

Parboiling of paddy

Rice parboiling involves soaking and steaming that results in gelatinisation of starch. Soaking, steaming and their duration are important parameters that determine the quality of rice as well as fixing vitamins / micro-nutrients in rice grains.

Soaking paddy

The purpose of soaking is to add moisture to paddy up to 30%. The soaking tank is filled with clean water (at room temperature). The paddy is then loaded into the tank and stirred to make the blank and immature lighter paddy to float on the water. Then the floating paddy (locally known as *chita*is removed from the tank. The water becomes dirty due to the presence of dust particles in the paddy when it is loaded into the soaking tank. This dirty water is required to be drained out within three hours. Fresh water is again poured into the tank and the paddy is kept for soaking for about 12 hours (freshly harvested paddy is soaked for about 6 hours) for single-steamed / single parboiled rice and for about 24-84 hours for double-steamed / double parboiled rice. Water is drained out every 12- hour and fresh water is supplied into the tank. To produce double-steamed rice, 5-7 minutes steaming is done before soaking.

The soaking tanks are usually made of brick, mortar, and cement plaster. These are generally rectangular or square in shape with different sizes depending on the capacity required. Each tank is constructed above ground level to permit easy draining of the soaked water. Tanks are loaded and unloaded by hand. Loading is relatively simple and easy but unloading is difficult.

Steaming/parboiling of soaked paddy

Steaming is carried out in a cylindrical hopper kettle. Kettles can be made of steel or concrete. In some cases, steaming tanks are made of old oil barrels (drum). Each kettle has a steam pipe in the centre. The tanks have a slide valve at the bottom. Steaming tanks are loaded manually with the soaked paddy. Steam passes through the soaked paddy and escapes through the upper mouth of the tank. After steaming is finished, paddy is discharged from the bottom of the tank. Several steaming kettles operated with each soaking tank permit a rotation of steaming operations. This minimises labour requirements and permits a virtually continuous operation of unloading the soaking tanks, steaming and unloading the steaming tanks.

The holding capacities of the kettles vary form mill to mill and depend on the mill capacity. Large capacity kettles have larger diameter and consequently paddy at the central part is over boiled, while paddy at the outer periphery is under boiled. Duration of steaming is different for single-steamed paddy and double-steamed paddy. Theoretically steaming period depends on the design and size of the steaming kettle/tank and on the steam flow as well as the seam pressure. If the holding capacity of the tank is large, longer period will be required. Arranging more than one steam pipe at strategic locations inside the kettle will ensure uniform steaming at a much more short time (Farouk and Zaman, 2002).

Steam boilers and furnaces

Husk-fired boilers are most commonly used in all traditional rice processing mills. Small boilers are used to produce steam and hot water for only the parboiling operation. Boiler size depends on parboiling requirements. Because 200 kg of steam is needed to parboil a ton of paddy, a parboiling plant with a capacity of 24 ton/day requires a boiler with a capacity of 4,800 kg of steam/day (Wimberly, 1983).

Boilers are locally made with lower grade steel sheet, even with old oil barrels / drum and are very much prone to accident. No pressure gauge and relief valves are attached to the boilers. Steam outlets are kept open to avoid excessive pressure in the boiler and the steam pipes and thus the hazard of explosion is minimised. Furnace is not properly built resulting in heat loss. For these reasons boiler efficiency is low.

Drying of parboiled paddy

Sun-drying is the only method of drying practiced in all the traditional rice processing mills. Every mill uses cemented floor (locally called *chatal*). Parboiled paddy should be dried to 14% moisture for safe storage or milling. Parboiled paddy is more difficult to dry and requires more energy than field paddy because its moisture content is much higher. However, higher air temperatures help reduce the drying time.

If drying is done too fast, internal stresses develop in the grain and cause breakage during milling. After drying is completed, the paddy should be allowed to stand for at least several hours – preferably for 1 or 2 days before it is milled, to permit internal moisture differences and stresses to equalise.

Parboiled paddy is sun-dried on large drying floors (*chatal*) close to the rice mill. A large number of workers are needed to constantly turn and mix the paddy to achieve rapid, uniform drying. For best results, paddy should be spread about 2.5 cm thick over the floor. At this thickness, one acre of drying floor can handle 60 tons of paddy. Depending on drying air temperature and relative humidity, sun-drying usually takes 1 or 2 days.

Rice husking and polishing

Engelberg type steel huller combines dehusking and polishing process into one operation. The hullers are installed in milling rooms with good concrete foundation and are powered by electric motors. Usually, two brands of steel net (horse brand and boat brand) are used for the hullers. Horse brand is thinner and the bran can easily pass through giving better quality rice. On the other hand, the boat brand net is thicker and the bran cannot be removed from the kernels; as a result rice quality is reduced. If the net is not replaced in time or if the net is repaired, quality of rice may be affected.

Vibrating sieves and fans for mechanical separation

For separation of head rice from husk, local made mechanically operated vibrating sieve along with a blower fan is used. The sieve is driven from the huller shaft. Rice bran and the broken are separated by hand.

Millers' Perceptions about Quality Rice

Paddy processing and rice quality

Although soaking, steaming and their duration are important parameters that determine the quality of rice, most of the rice millers and their technicians are not aware of the optimum conditions for soaking and steaming. They also do not bother much for the quality of rice. The reasons behind this fact are (i) traditional methods and procedures are followed by the rice millers, (ii) they think that the methods and procedures they follow are correct, (iii) nobody tells them about the optimum conditions, and (iv) no books or pamphlets on rice milling technology are available to them (Farouk and Zaman, 2002).

Again, parboiling results in inward diffusion of water-soluble vitamins, in addition to partial degradation of thiamine during heat treatment (Padua and Juliano, 1974). Despite the degradation of thiamine, parboiled milled rice has a higher vitamin content than raw milled rice (Padua and Juliano, 1974). Thus, parboiled rice has positive effect on nutrition. Further, parboiled cooked rice grains are less sticky, do not clump and are resistant to disintegration; the grains are also harder.

It was found that in the cases of 37% traditional mills, paddy was parboiled for milling. Those who parboiled paddy, 27% of them parboiled paddy once, while the rest 73% parboiled twice. The reasons for parboiling once or twice were explored from the millers' point of view. The reasons for parboiling one time were reported as: nutrition value in rice grain is maintained, rice becomes tasty, good colour of rice is maintained and rice grain remains unbroken. This indicated that the millers who parboiled once have some misconceptions about the impact of parboiling once or twice.

On the other hand, the millers who parboiled paddy twice reported that the most important reason for parboiling twice was less breakage of rice grain as reported by 39% of the millers. The second most important reason was amount of rice increases as reported by 33% of the millers. The other reasons for parboiling twice were rice becomes hard as reported by 16% of the millers, good market price (6% millers) and rice becomes tasty (6% of the millers).

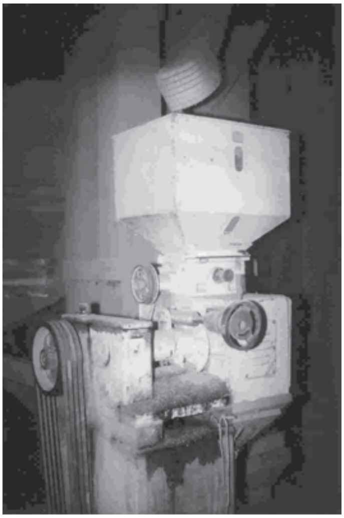
Millers perceptions about quality rice and actions taken

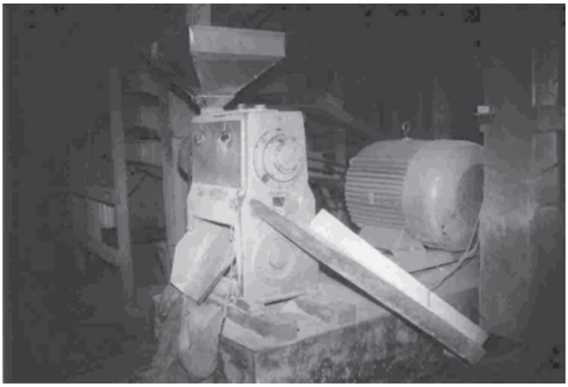
By the term good quality of rice, 39% of the millers think that rice should be cleaned, 35% of them think that rice should not be broken and the rest 26% think that rice should have slender grain. To get good quality of rice, 79% of the millers polish rice once which is the minimum requirement to make rice edible. However, for making it whiter and to get slender rice, 21% of them polish rice more than once.

The term "polished rice" refers to milled rice that has gone through polisher that remove loose bran adhering to the surface of milled rice and improve its translucency (Juliano, 1993). In the case of traditional / mobile mills, Engelberg type steel huller combines the husking and polishing process into one operation. Milling of parboiled paddy is completed in 2 / 3 passes depending on quality of polishing desired.

On the other hand, in the cases of semi-automatic or automatic rice mills husking paddy is done by rubber roll huller and polishing is done separately using separate polisher. Usually rubber polisher is used, however, stone polisher is also used as reported by the millers. The polisher has a horizontal or vertical cylinder or cone, covered with leather strips, that gently removes loose bran as it is rotated in a working chamber made of a wire-mesh screen or a steel screen with slotted perforations (Juliano, 1993). In this case, desired level of polishing is achieved automatically by fixing different degrees of polishing desired. The responses from the millers revealed that to achieve good quality of rice some millers give importance to make it more white and slender ignoring its nutritional value.

Figure 6
Huller and Polishing Unit of Semi-Automatic Rice Mill





About one-third of the traditional mill owners purchased paddy for selling rice after husking. About 78% of them polished rice once and the rest 22% polished twice. However, in the case of mill owners who returns all husked rice to their customers / paddy suppliers, all of them polish rice once. It was reported by the millers that at least one polishing is required for making rice edible . The most important reason for more polishing rice as revealed from responses of the millers was to get clean rice (45% of responses), followed by high market demand / better price for more polished rice (33% of responses), nice looking of rice (14% of the responses) and to make rice slender (8% of the responses). The term "nice looking of rice" has been used here to mean a combination of characteristics of rice; like the rice which is clean, bright and slender. This is a subjective assessment of rice quality by the millers/ consumers, judged by just looking at the rice grains.

It was reported that about 82% of the rice business men requested the millers for one time polishing, while the rest 18% requested for polishing twice. This implies that to get higher price, some (18%) businessmen are ignoring loss of nutrient value in rice grain polish rice twice. However, 100% of the farmers in the case of husking paddy for own consumption asked for polishing rice once.

Rice is normally polished once for which about 1 kg weight is lost (in terms of bran) per 40 kg of paddy. However, for polishing twice, about one additional kg of rice is lost in the form of bran the value of which is about Tk. 3.00, which is retained by the customer (rice millers / businessmen in this case who husk paddy for business). On the other hand, the value of lost rice (1 kg) is about Tk. 15 / 16. Therefore, net loss is about Tk 12/13. However, this loss is largely compensated by additional profit by charging higher price of more polished rice.

In the case of traditional mills, polishing more than once does not make significant differences in brightness of rice so the price increase of polished rice is not that much. It can be seen from the photographs that minor differences exist in single polished and double polished rice, however, close observation will reveal that single polished rice contains some un-husked rice as well as more bran and small broken rice compared to double polished rice.

On the other hand, in the cases of semi-automatic and automatic rice mills, significant changes in brightness as well as changes in shape / size of the rice grain can be observed which leads to considerable increase in price of polished rice. In this case, the extent of rice polishing depends on fixing the degree of polishing desired by the miller. To get abnormally high price from the customers, sometimes highly polished rice is sold in the name of other better variety of rice. For example, highly polished Pajam variety is converted to look like Nizershail (Photograph) and sold as Nizershail. The price difference of these two varieties of rice in the retail market is about 4 to 5 Taka per kg and about 1 to 2 Taka per kg in the wholesale market. Similarly, highly polished BRRIdhan28 is sold as Pajam. Needless to say, polishing of rice to such an extent causes considerable loss of mico-nutrients from upper layer of rice grains.

Case Study: Semi-automatic rice mill

Only one Semi-automatic rice mill was found in the study area. The owner of the mill was Mr. Babul Islam of the village South Butina under the Union of Akcha in Thakurgaon Sadar Upazila of Thakurgaon district. Mr. Babul had

HSC level of education and his main occupation was business although he also had large agricultural land holding (10 acres). The mill was established in the year 2002 and the machineries for it were made of China. The husking capacity of this mill was 1 ton / hour. Paddy drying facilities (*chatal* size) for this mill was found to be larger than that of traditional mills. About 12 tons of paddy could be dried at a time.

Out of total paddy husked about 50% of paddy was purchased by the mill owner for business purpose who ultimately sold it as husked rice. Paddy storing capacity of this mill was about 200 tons, which was much larger compared to that of traditional rice mills (80 tons on the average). However, the paddy was stored for the period of maximum one month in both *Boro* and *Aman* seasons. The loss of stored paddy due to attack of pests or rats was reported to be 1%. To minimise the loss measures particularly for killing rats were taken.

From the view point of the miller, good quality of rice means clean rice and the rice which is less broken. Further, it also means slender rice grain. Paddy is parboiled twice and the most important reason for parboiling twice was less breakage of rice grain followed by the reasons of good recovery from husked paddy and nice looking of the rice and good taste of the cooked rice. According to the miller, the main reason for polishing rice is to make it more white. Generally, farmers as well as businessmen ask for polishing rice once, however , more polishing is done for more cleaning of rice, the market demand as well as for higher price. About 26 kg of rice and 1 kg bran (worth Tk. 5) are derived from husking 40 kg of paddy. The quality of rice bran in semi-automatic rice mill was reported to be better compared to traditional mills, the price of which was also higher. Rice is less broken and more polished in this case compared to traditional / mobile rice mills which implies loss of more micro-nutrients from the rice grain although higher price of rice is achieved

Consumers' Perceptions and Preferences for Quality Rice

Consumers' perceptions about good quality of rice

Consumers' perception about good quality of rice for consumption was assessed through their specifications of three choices in order of importance. Accordingly, the first choice for good quality of rice was given for slender rice (42.7 % responses) followed by taste for eating (24.4 % responses) and clean rice (17.0 % responses). Again, from multiple responses (3 choices from each

Table 1
Perception of Consumers about Good Quality of Rice

Consumers' Perceptions about Good Quality of Rice	**Response for Most Important Quality**		**Multiple Choics of Quality (Compiled for all)**	
	No. of Responses	**Total (%)**	**No. of Responses**	**Total (%)**
Slender (thin) rice	430	42.7	580	23.2
No bad smell	14	1.4	163	6.5
The rice which has good smell	19	1.9	110	4.4
Clean rice	171	17.0	337	13.5
Tasty for eating	245	24.4	754	30.2
Less broken rice grain	40	4.0	256	10.2
Less black / dead rice	9	0.9	82	3.3
Hard rice	15	1.5	83	3.3
The rice which increases after cooking	35	3.5	143	5.7
Old rice	4	0.4	98	3.9
Nutritious	18	1.8	108	4.3
The cooked rice of which remains good for long time	2	0.2	34	1.4
Insect free rice	1	0.1	3	0.1
The rice which is boiled quickly	3	0.3	8	0.3
Total	1006	100	2499	100

Source: Author's survey.

respondent) of the consumers, it was revealed that tasty for eating ranked first (30.2% responses) followed by slender rice (23.2% responses), clean rice (13.5% responses) and less broken rice (10.2% responses). The other less important qualities of good rice as assessed by the rice consumers can also be seen in the Table 1.

Methods of paddy husking and rice quality

In the case of rice consumption from own production, about 61% of the consumers husked paddy using traditional mills, while about 12 % of them used mobile mills and the rest 27 % used both traditional and mobile mills. In response to a question whether there is any quality difference of rice if paddy is husked by traditional mills and by mobile mills; about 24 % of the consumers said yes, 14% said no and majority of them (62 %) said that they had no idea about the quality difference. In fact, husking quality (fineness) of rice depends on size of the mills (Baqui *et al.*, 1994). With the increase of size of the mills (engine horsepower), the fineness of rice improves. Since most of the traditional mills recently established in rural areas are of small size (very close to mobile mills), it was very difficult for the majority of the consumers to distinguish milling quality of traditional mills compared to that of mobile mills.

However, those who reported that there is quality difference, in specifying the differences, most of them (about 78 % of respondents) said that rice is more clean if husked by traditional mills instead of mobile mills. Other differences as mentioned by the consumers were less broken rice grain (about 16% respondents) and more fine / slender rice (about 6 % respondents).The survey also revealed that in about 82 % cases paddy was parboiled once. Only about 18% of the respondents parboiled twice for husking paddy. Further, in 97% cases paddy was parboiled at home and in the case of rest 3%, parboiling was done at the mill premises.

Rice polishing

About 82 % of the rice consumers who husked paddy from own production, reported that polishing was requested to the millers after husking paddy. However, only one polishing was requested almost in all cases (99.7 % cases). It was found that about 87% of the customers knew that they get less rice for polishing rice. The rest 13% were not aware of this. Again, it was found that about 89 % of the customers (who polished rice) knew that for polishing rice, vitamin / nutrition is lost. The rest 11 % had no idea about the loss of vitamin / nutrition for polishing rice.

The respondents were asked to explain the reasons for rice polishing. The most important reason for polishing rice was found to be for more cleaning of rice as reported by about half (48.7 %) of the consumers (Table 2) followed by the reason of making rice nice looking (35.7 % of responses). From multiple responses (combining all three choices), it was found that most important

Table 2
Reasons for Giving Priority for Rice Polishing

Reasons	**Responses for First Most Important Reason**		**Multiple Choics of Quality (Compiled for all)**	
	No. of Responses	**Total (%)**	**No. of Responses**	**Total (%)**
For more cleaning	296	48.7	324	25.7
For making rice more tasty	32	5.3	304	24.1
For making rice nice looking / fine	217	35.7	274	21.8
Rice becomes slender	25	4.1	115	9.1
More price is received	38	6.3	231	18.3
Rice becomes soft	-	--	12	.08
All	608	100.0	1260	100.0

Source: Authors' survey.

reason for polishing rice was for cleaning rice (25.7% response) followed by for making rice more white (24.1% responses) and for making rice nice looking / fine (21.8% responses). The other reasons for preferring less polished rice by the consumers can be seen in Table 6.

Type of rice purchased (parboiled /non-parboiled)

About 96 % of the consumers bought parboiled rice from the market for consumption, while only about 4 % of them purchased non-parboiled (*atap*) rice. The most important reason for eating parboiled rice as reveled from the responses of consumers was found to be their habit (of eating parboiled rice) as reported by 57.4 % respondents (Table 3). This was also found to be the most important reason from compiling multiple responses (39.8 % responses). The other reasons of eating parboiled rice as revealed from multiple responses were: parboiled rice is not sticky (15.7% responses), it is easily digestible (15.2% responses), the rice is tasty (13.2% responses), it remains in good condition for longer time (12.2 % responses) and cooked rice increases in quantity (3.8% responses).

Table 3
Reasons for Taking Parboiled Rice

Reasons	Responses for Most Important Reason		Multiple Choics of Reasons (Compiled for all)	
	No.	**Total (%)**	**No.**	**Total (%)**
Habituated to eat parboiled rice	344	57.4	476	39.8
Parboiled cooked rice remains good for longer time	61	10.2	146	12.2
Parboiled rice is tasty	49	8.2	158	13.2
Parboiled rice is easily digestible	69	11.5	182	15.2
Parboiled cooked rice is not sticky	53	8.8	188	15.7
Cooked parboiled rice increases in amount	23	3.8	46	3.8
All	599	100.0	1196	100.0

Source: Authors' survey.

Consumers' preferences of rice in relation to milling practices

Consumer's preference of rice for consumption according to the process of rice milling is assessed through asking them the type of rice they prefer and the reasons for that. It is found that most of the consumers (58.8%) prefer less polishing milled rice (Table 4). Next to this, the preference is given for rice husked by traditional method (*dheki*) as reported by 26.9% of respondents. Further, 14.2% consumers report that their preference is milled rice with more polishing. Again, it is found that almost all of them (about 99%) know that rice husked by mills is more polished compared to that of husked by *dheki*. The findings indicate that the most of the rice consumers are concerned about nutrient content in rice grain related to milling practices.

In the case of preference for milled rice, there are two choices: one is with less polished rice and the other is more polished rice. The reasons for choosing more polished or less polished rice are further explored through asking them the reasons for their choices.

Table 4
Types of Rice Preferred by Consumers by Milling Practices

Milling Practices	Consumers Preference	
	No. of Responses by Consumers	Responses (%)
Rice husked by *Dheki*	271	26.9 %
Less polished milled rice	593	58.9 %
More polished milled rice	143	14.2 %
All	1007	100.0 %

Source: Authors' survey.

Table 5
Reasons for Preferring More Polished Rice

Reasons	Responses for Most Important Reason		Multiple Reasonses of Reasons (Compiled for all)	
	No.	Total (%)	No.	Total (%)
For getting bright / nice looking rice	91	63.6	107	30.0
Cooked rice is good	17	11.9	74	20.7
For consuming slender rice	20	14.0	44	12.3
Rice is tasty	15	10.5	85	23.8
More demand in the market	-	-	37	10.4
More price is received from the market	-	-	10	2.8
All	143	100.0	357	100.0

Source: Authors' Survey.

In the case of preference for more polished rice, the most important reason as identified from the responses is to get bright/nice looking rice as reported by about 64% of the consumers (Table 5). From multiple responses also, this is found to be the most important reason of more polishing rice (30% responses). The other reasons according to relative importance are rice becomes tasty (23.8% responses), cooked rice is good (20.7% responses).

On the other hand, the most important reason for preferring less polished rice was found to be consumers' awareness about nutritional value as reported by about 59% of the respondents. From multiple responses awareness of nutritional value again found to be the main reason of preferring less polished rice (43.1% responses) followed by the reason of more recovery of rice from paddy (31.6% responses). There are other reasons too as can be seen in Table 6. However, those who consume less polished rice, it is clear from their responses that they are well aware of nutritional value in rice grain related to rice polishing.

Table 6

Reasons for Preferring Less Polished Rice by Consumers

Reasons	**Responses for Most Important Reason**		**Multiple Choices of Reasons (Compiled for all)**	
	No.	**Total (%)**	**No.**	**Total (%)**
Much nutritional value	351	58.9	493	43.1
More rice is recovered from paddy	135	22.7	362	31.6
Less breakage of rice	35	5.9	133	11.6
Less husking cost	2	0.3	14	1.2
Tasty for eating	48	8.0	98	8.6
Good cooked rice	9	1.5	15	1.3
Rice can be purchased at less price	16	2.7	29	2.5
All	596	100.0	1144	100.0

Source: Authors' Survey

Conclusions

A number of paddy processing activities as well as milling itself, which were traditionally done at home particularly by women are now done mechanically. Rice milling by *dheki* has almost disappeared and it is done by mostly traditional rice mills as well as by a number of semi-automatic and automatic rice mills. Mobile rice mill is a new addition to traditional rice mill, which uses power tiller or shallow tube well engine for paddy husking. Quality of milled rice and its nutrient content in the grain largely depends on methods of paddy processing and the type of rice mills used. However, perceptions of both millers and consumers about quality of rice and their preferences play an important role in selecting method of rice processing and milling.

Based on primary data, the study showed that in most of the cases when consumers husk paddy from own production, paddy is parboiled once which means most of them are not aware of positive effects of parboiling twice, particularly in relation to inward diffusion of water soluble vitamins in rice grain. On the other hand, in the case of millers who purchase paddy for doing business by selling husked rice, it was found that most of the millers parboiled paddy twice. However, this is not on nutritional ground rather because of the fact that it makes rice grain harder as a result there is less breakage of rice grain.

More uniform, less broken, slender, whiter polished rice are produced as one moves from traditional to larger type of rice mills (including semi-automatic or automatic rice mills). The price of such fine rice is also higher in the market as it looks good and the cooked rice is tastier although more polished rice implies more loss of nutrients from the rice grain. The extent of polishing depends on demands from both the consumers / rice traders as well as millers. Rice is normally polished once when the miller husk customers' paddy. However, when they do business by purchasing paddy and selling it as husked rice, in some cases, they polish rice more than once to make it slender and whiter to get higher price. Even using modern technology of polishing devices, the large rice mills convert coarse rice grain into finer quality of rice charging higher market price in the name of other good quality of rice. By the term good quality of rice, most of the consumers understand slender rice which has better taste and which is cleaner. All these means, more polished rice which implies less content of micronutrient. The urban upper middle class as well as economically better off household are the main customer of "fine" quality polished rice containing less micro-nutrient in the grain. However, most of the consumers in general report that they prefer less polished rice on nutritional ground.

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Chapter 11

Rice Milling Technology in Bangladesh: Characteristics and Productivity

M Asaduzzaman and Nazneen Ahmed

Introduction

Rice or rather paddy (i.e., rice in husk) must be first processed to remove the husk (outer shell of paddy) and bran (inner coating over the kernel) to produce white rice which is consumed in many countries including Bangladesh. With improved cultivation and harvesting methods, the rice output of Bangladesh has increased from 12 million metric tonnes in the 1970s to nearly 34-35 million metric tonnes at the end of the first decade of the 21st century. This is in terms of processed rice which means that the output of paddy to be processed has been 50 million metric tonnes or more. The rising output of paddy has increased demand for milling (to dehusk and remove bran). Thus over time, rice milling has become a major agro-processing industry critical to steady supply of rice for food security.

There are basically two ways to dehusk paddy and remove bran. One is manual and the other is mechanical. The *dheki* is the main manual technology in which the pestle is iron tipped and fixed to a foot-operated long and thick pole and the mortar being a lined hole in the ground. The mechanised means now come in the form of a variety of machines operated by diesel or electrically driven motors along with various separating tools for the rice from husk and bran at different stages of operation. There is also a bewildering array of rather small, practically portable husking machines which are used by villagers. So at one end there is the traditional *dheki* which is almost but not yet out of the scene and on the other spectrum are the large automatic rice mills which demand a ready supply of bulk of paddy for continuous operation. On the other hand, while mechanisation has advanced particularly in actual milling in more recent times (see later), most of them are preceded by rather inefficient parboiling system wasting energy. In any case, the productivity, technical efficiency and scale economics of these technologies is likely to be vastly different with major implications for food security and employment.

Technical efficiency in milling and the technology in use are major factors behind productivity and quality of output. Higher productivity and quality obviously have implications for better supply and thus for food security. Thus to understand the productivity behavior over time, technical efficiency in milling should be explored. A highly automated and fast technology in milling means that such firms must ensure steady supply of paddy. Stock behaviour of auto mills and others as well as networking with marketing agents and sellers of paddy, may help explain paradox of rising price of rice despite high production levels of paddy. The hypothesis may be that due to higher productivity and capacity, auto rice millers need to stock paddy more than others. One thus needs to understand the dynamics of moving from traditional to modern rice milling, the productivity, costs, stock behaviour which have major implications for rice price, employment generation and overall national food security.

Auto large mills are reportedly fewer than others but have much larger capacity and apparently higher productivity with potential oligopoly in rice market and monopoly in paddy market: Thus having potential destabilising power and control over market intermediaries as often alleged. Furthermore, government provides a floor price for paddy and rice at which it will procure under its public procurement system. The procurements are mostly from the millers. As large mills are capable of supplying more than the smaller ones, it is administratively easier for the Government to procure from them. Highly automated and large rice millers, though few in numbers have the power to destabilise market through their large volume of operation both in paddy and rice markets.

There is yet another aspect related to food security which relates to the quality of milling or the final rice that comes out of the mills. In Bangladesh, several grades are used to mark the quality of milled rice. As these gradations are related to the extent of removal of husk and bran, the cleaner the rice looks a better price it may fetch in the market. However, highly polished rice may have certain nutritional elements (such as vitamin B) reduced or eliminated from the kernel which explains why the *dheki*-processed rice is often sought after by the health-conscious persons. In that case, the *dheki*-processed rice may have a premium on it. Exactly how the two considerations work out in practice is an empirical issue. In any case, the state of processing and by implication the nature of milling has certain connotation for nutritional aspects of food security.

Available studies on rice milling in Bangladesh or for other countries (for example, Ahiduzzaman and Islam, 2009; Furuya and Sakurai, 2003) mostly concentrate on energy consumption in rice mills, their capacity utilisation, efficiencies in terms of rice recovery rate from paddy or on shortcomings of the rice mills. However, a comprehensive study on efficiency of rice mills covering social and economic implications and thus for food security is hard to come by. This study tries to fulfill that gap in literature. This study investigates the behaviour of various rice milling firms and analyses socio-economic implications of various milling technologies.

The following Section 2 elabourates various rice milling technologies, while Section 3 discusses operational characteristics of various rice mills and their efficiency. Section 4 summarises the findings and concludes with policy prescriptions.

Rice Milling Technology

Definition of Rice Milling

Defining rice milling can be a tricky one as it varies with technologies and also with countries. In short, rice milling includes the operations of hulling, polishing and whitening of rice grain. Hulling involves removing the husk from the paddy without removing the bran from the endosperm. Polishing and whitening, however, involves the separation of bran from rice endosperm and providing a shining appearance. In most cases, actual milling has to be preceded by parboiling for better grain quality and lower breakage of kernel.

In Bangladesh, the rice milling technology has passed three broad phases. However, technologies of all these phases are simultaneously prevailing. These are i) traditional rice milling system, ii) Engelberg (steel huller) milling technology, and iii) modern rice milling technology (with rubber huller and mechanised drying). Whatever is the technology, the milling of rice follows mainly four major steps. The very first step is *cleaning*. When the raw paddy comes to the mills, it contains stalk, stones, dust and soil, etc. So it needs to be cleaned first. More often than not in the next step, paddy has to be parboiled which allows for better quality milling as well as certain chemical changes in the kernel altering its taste. Thirdly, the outer rough shell of paddy is moved. This step is known as *shelling/ husking*. Mostly the Rubber roll sheller is used to complete this process. In the fourth step grading takes place. In this step, the broken rice is separated from the whole one by using grading sieves. Before this fourth step, two other steps are followed by some mills mainly the modern ones. One of these two steps is *whitening*, where the bran is removed from the rice kernel. In the other step, the whitened rice is being polished by rubber polisher. *Polishing* takes place because the whitened rice may have bran with it.

The clean rice that is obtained after completion of the milling process is about 67% of the paddy weight. Husking is the most labour intensive operation in the whole postharvest processing and accounts for more than 50 percent of the total post-harvest labour requirement (Ahmed, 1981).

Basic Characteristics of Various Rice Milling Technologies

Traditional Milling System

Of the common traditional rice milling technologies in Bangladesh, *dheki* had been the most ubiquitous. A *dheki* is a manual device, which consists of a wooden lever, usually about six feet long and six inches in diameter. It moves on a small bolt passing through it and two cheeks, which are driven into the ground, until the bolt is about 18 inches high. Three women operate this together (a minimum of two is required), two raising the beam with their feet and the third keeping the container filled with paddy and turning the paddy. *Dheki* had been widely used in rural Bangladesh. Usually women operate this device. Its capacity is only about 30 to 40 kg of clean rice/day.

Engelberg Milling Technology

The Engelberg huller consists of a cylindrical rotor fitted in housing. The bottom half of the housing is fitted with a slotted sheet called sieve. The rotor is driven by a motor or an engine with a suitable drive arrangement. About 85% hullers are Small Engelberg hullers. This is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. This results in a large proportion of broken kernels, a low white rice recovery of 50-55% and head rice yields of less than 30% of the total milled rice. Capacities of these mills vary from 350 to 550 kg per hour (No. 8 huller) to over 1200 kg (No. 2 huller). A typical rural mill is powered from a, 15–25 hp. electric or diesel engine.

Large Engelberg rice mills employ a slightly improved system for rice processing. These are the most popular and locally called *chatal*. In Bangladesh, these are widely used technological establishments for rice processing and the milling capacity of this type of rice mill is more than 1000 kg/hour. It has low white rice recovery with many broken kernels. The Engelberg rice mill has neither a paddy cleaner nor a rice grader.

Modern Rice Milling

These include modern mills either of semi automatic (also called major) or fully automatic mills. In the semi autos, there are some intermediate improvements of the husking rice mill by replacing the Engelberg huller only while the drying process remains manual. Major mills are thus not fully automated. Such mills usually have large boilers for parboiling paddy. These major mills mainly use under runner disc sheller and also use the rubber roller huller for de-husking.

In the modern large automatic rice mills, the paddy is pre-cleaned before soaking at high temperature and parboiled under pressure by steaming. Then paddy is dried in a dryer and husked by rubber roll sheller. The un-husked paddy is separated from the brown rice by a paddy separator and is recycled back to the huller. The brown rice is polished.

Over the years, some technological improvements have been introduced in rice milling including (1) parboiling the paddy to conserve its vitamins, harden the grains and reduce the proportion of broken rice, (2) mechanical drying of paddy, (3) use of rubber roller sheller to minimise grain breakage, (4) utilisation of husks as fuel for broilers and dryers and as raw materials for products, such as cement and (5) evolution of mechanisms to separate rice bran from husks to extract oil from rice bran. Rice bran is also used as good feed for fish and poultry. Some of these have been integrated in large automatic mills while some others like oil extraction from rice bran have developed as separate activities in other enterprises.

Rice Mills by Types

There is not much reliable information on the actual number of rice mills in Bangladesh. According to a report of DFID (2002), there are roughly 100,500 rice mills of different sizes and categories spread throughout the country. Out of the total number of rice mills, about 100,000, i.e., practically all were of Engelberg type and the rest of Chinese automatic and large automatic type.

The most reliable secondary source of information on rice mills of Bangladesh may perhaps be from The Census of Manufacturing Industries/Survey of Manufacturing Industries (2005-6, 2010). According to the report, of the total number of establishments of rice milling industry, presumably in 2005/06 or there about in Bangladesh was 3864. The number appears rather small and may have to do with the sampling technique of the survey on which the number is based. Be that as it may, the classification of the industry according to the employment structure shows that most of the rice mills in Bangladesh are small (58%) having less than 20 employed persons and somewhat larger (39%), employing 20-49 persons.

Table 1

Number of licensed Rice Mills in Bangladesh, 2011

Divisions	**Husking (*Chatals*)**	**Major or Semi Auto**	**Auto**	**Total**
Rajshahi	5242	2	48	5292
Rangpur	6361	20	110	6491
Dhaka	2430	64	105	2599
Khulna	1932	21	14	1967
Chittagong	307	11	74	392
Sylhet	51	0	10	61
Barisal	24	13	0	37
Total	**16347**	**131**	**361**	**16839**

Source: MoFDM (2011)

In 2011, a survey was done by the then Ministry of Food and Disaster Management of the Government of Bangladesh. This survey mainly provides the number of licensed rice mills in different districts of Bangladesh which are contracted for rice procurement by the government. According to this survey, the total number of licensed rice mills in 2011 *boro* season was 16,839 (Table 1). The total number will certainly go high if the non-licensed mills are considered. Of the total number of mills, 16,347 or 97% were husking mills of the Engelberg type. The number of major mills was only 131 in Bangladesh and of automated rice mills only 361.

Among the seven divisions of Bangladesh, most rice mills are located in just two divisions, namely Rangpur and Rajshahi. These two divisions account for 38.5% and 31.4%, respectively, of rice mills. However, when the mills are categorised by type, it is found that most automatic mills are in Rangpur (30%) and Dhaka (29%) followed by that of Chittagong (20%). As none of these divisions are major rice growing and surplus areas, apparently the industrial location of the modern automatic rice mills have other considerations than supply from the vicinity. We shall later see that the supply lines are indeed long in the case of such mills.

The Ministry of Food also maintains a list of rice mills to procure rice for buffer stock of food for the country. For this, the Directorate General of Food (2005) enlisted about 25,000 of small rice mills and 500 large rice mills throughout the country. However, according to other sources, there are nearly 100,000 rice mills in Bangladesh, which include small, medium and the large ones.

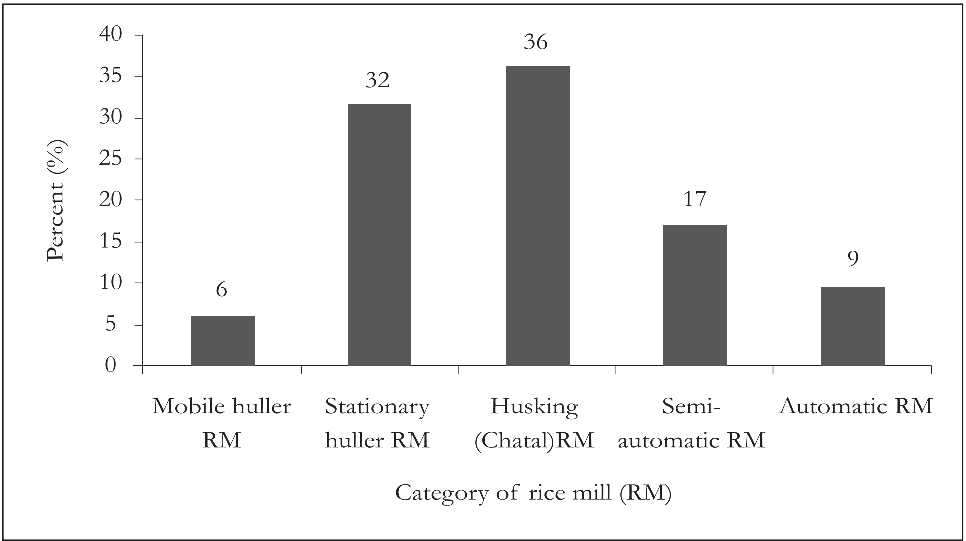
Operational Characteristics of Rice Mills and Their Efficiency

The Study Sample

The analysis in this paper is based upon a sample survey drawn from a population of the licensed mills from the survey of mills. The details of sampling may be found in the main report (Asaduzzaman *et al.*, 2013). A summary of the sample is presented in Figure 1. Note that, there was an attempt to sample also mobile hullers and small but stationery hullers. Much of the analysis is, however, based upon the other four categories.

Most of the surveyed rice mills were of conventional steel roller/ Engelberg or stationery small huller category. Mobile hullers are comparatively a few in number but this should not be construed to mean that they are less numerous than others. Being mobile, it was hard to locate them within a given space at any given time. On the other hand, if the mobile hullers serve small farm households who produce only small amounts and, therefore, mill only a little at a time, while it is believed that these hullers have replaced the earlier manual *dhekis*, then the relative number of mobile hullers may be much larger than what is suggested in the sample.

Figure 1
Categories of Rice Mills in Sample Survey
(N= 403)



Characteristics of Different Rice Milling Technologies

Ownership of Mills

About one fourth of the sample rice mills are semi- automatic and fully automatic mills (26%), while two thirds of the mills are husking (*chatal*) and stationery huller types (Figure 1). Most of the mills are owned by a single entrepreneur. Comparatively only in a few cases are the mills owned jointly. Joint ownership appears to be much more frequent in the case of semi-automatic mills (50%). In the case of hullers again almost all are owned by a single entrepreneur.

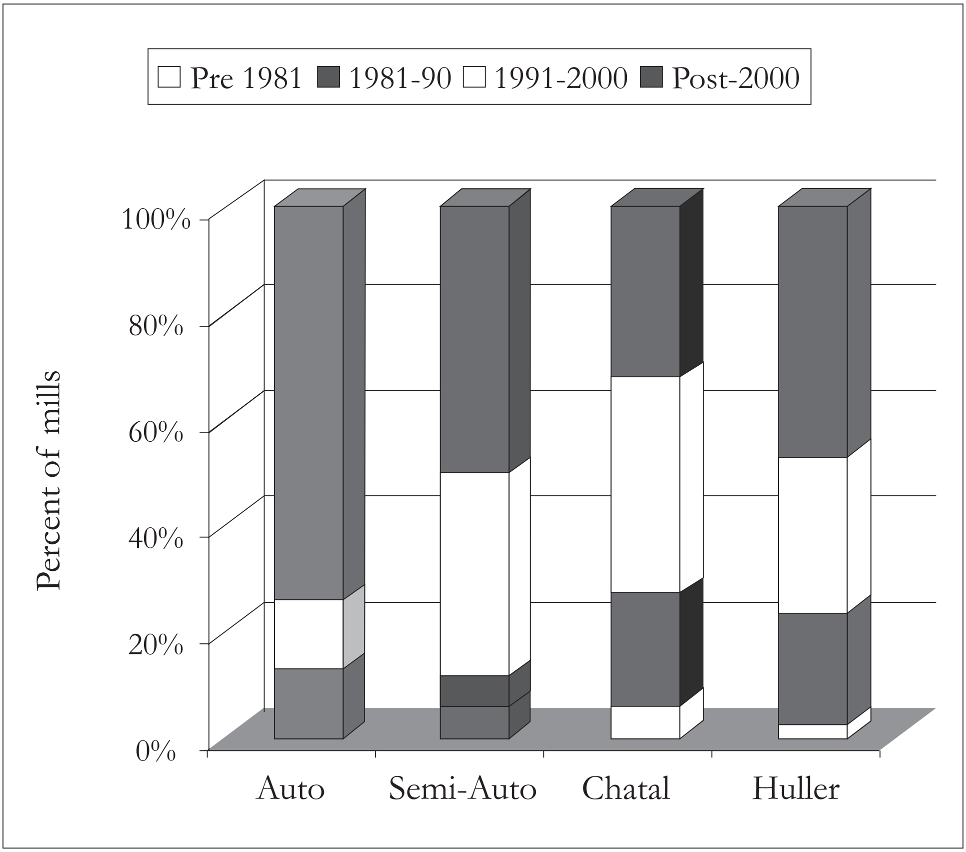
Year of Establishment

Most mills were set up recently, more than a third over the last one decade or so while another 44% was established during the decade previous to the present one. The advent of automatic rice mills is a comparatively recent phenomenon. This is borne out by the decomposition of year of establishment by category of mills (Figure 2). Out of 38 sample auto mills, 25 or 66% have been established since 2005 onwards, while for semi-auto mills, a good number (28 out of 70 or 40 %) have been set up since 1998. For Engelberg mills, there was no definitive pattern. Hullers entered the scene all over the period, but roughly half are in operation since 2000 or there about. What all these mean is that over time, there may have been a tendency of polarisation in milling technology which has become sharper in more recent years.

Types of Rice Processed

Three different types of rice are processed in the country, parboiled, sun-dried and those for making puffed rice. Parboiling is the norm. Husking rice mills (*chatal*) produce 97.2% parboiled rice and only 2.8% percent unparboiled,

Figure 2
Year of Establishment of Rice Mills



sun-dried (*atap*) rice of the total rice processed by them. The proportions for semi-automatic rice mills are 75.7% parboiled rice and 24.3% unparboiled, while for the automatic rice mills these are 84.2% parboiled rice, 7.9% unparboiled rice and 7.9% puffed rice. Thus only the automatic rice mills process rice of all three types, while the other two types of mill process only parboiled or *atap* rice the proportion of latter being significant only for the semi-automatic ones.

Drying Technology of Rice Processing

Sun-drying is the norm in husking mills. Sunshine drying needs 2-3 days for paddy. Sometimes, the time may be lengthened due to cloudy or rainy weather. An alternative to sun-drying is mechanical drying in a dryer, used generally in automatic mills. Compared to the longer time requirement in case of sun-drying, mechanical drying needs only up to 10 hours depending on the moisture content of paddy. Sometimes, a combination of sunshine drying and mechanical drying are observed.

Parboiling Technology of Rice Processing

Prior to actual dehusking, paddy is often parboiled in hot steaming water. This process hardens the grain, makes for better milling and lower percentage of breakage. Traditionally a pan or pot is used to parboil paddy. Over the years, the technology has changed. In commercial rice mill, the paddy is parboiled with steam. Steam is produced in locally made low pressure boiler and released in the parboiling bin containing paddy. This process is done batch by batch. The paddy loading is done manually.

The other type of parboiling is that done in the automatic system. In this system, paddy is loaded by elevator in the soaking tank. After soaking, the paddy is fed in the parboiling bin automating by opening the port at the bottom of the soaking tank. Then steam is released in parboiling bin from an automatic boiler. After parboiling, the paddy is released from steaming bin and carried by elevator to dryer.

There are two types of boiler used in rice parboiling system. One is locally made low pressure boiler mainly used in husking rice mills and the higher pressure certified boiler, which is used in automatic rice mill. In many cases, locally made boilers are also used.

Cost of Machineries

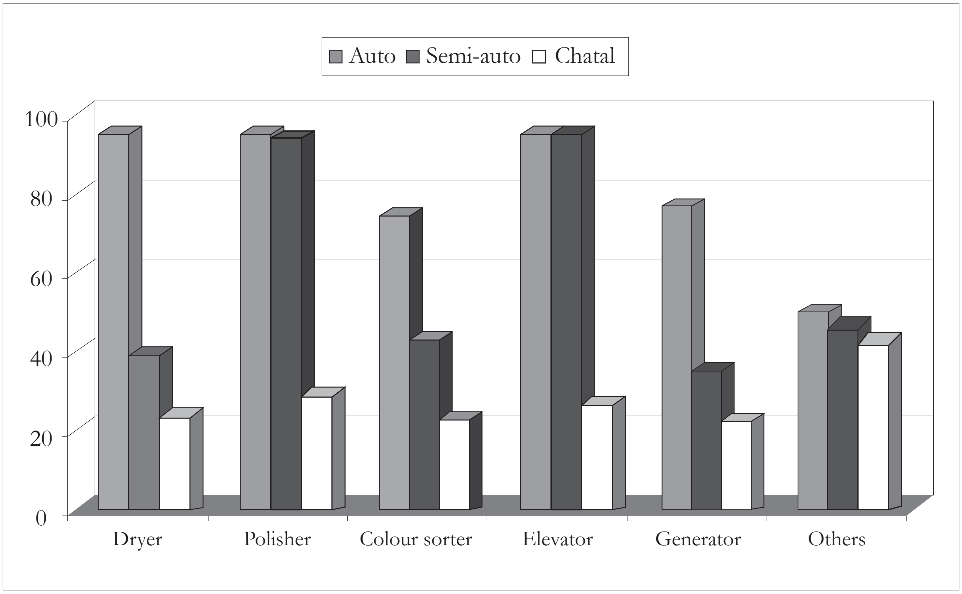
What differentiates the automatic rice mills from the others is the high cost of capital as these mills use various types of machineries of which some are very costly. Some idea of this may be obtained from the figure below. Rubber shellers, the hall mark of auto rice mills, are on average 5 times as costly as a steel sheller (used in Engelberg plants). Obviously at any given point in time, the machines will be a mix of old and new. Thus, one finds a maximum value of a steel rollers to be Taka 200 thousand, while the maximum price of a rubber sheller can be as high as Taka 1,500 thousand. Again colour sorters, another hall mark of many auto mills are also extremely costly, the average being Taka 3 million while the maximum is Taka 10 million. Polishers, equipment usually found in auto mills, are also very costly, Taka 450,000 on average but the maximum (presumably for a new one) can be as high as Taka 10 million. What all these suggest is that automatic rice mills have to invest hefty sums for capital machineries.

Types of Machineries Used by Different Rice Mills

While there are major differences in capital intensity by type of mills, it may be that some of the trappings of the automatic mills may be also adopted by the semi-automatic and Engelberg mills for remaining competitive in the market,

Figure 3

Types of Machineries and Facilities in Rice Mills (% of Mills)



Thus, we find that the basic machineries like shellers and boilers are there in every mill (in fact without them a rice mill cannot operate), dryers are owned by some semi-auto and Engelberg mills but, much less frequently than auto mills (Figure 3). Indeed, even polishers and colour sorters are also sometime owned by semi-autos and much less frequently also by *chatals*. So is the case with elevators and generators for power production. Thus, while there is a vast difference in the basic technology across rice mills, some of the machineries generally found in the automatic mills are also now being used by other types of mills.

The other characteristics of the capital assets is that much of these has been procured comparatively recently which is not surprising given the pattern of establishment of the mills being generally during the more recent times for automatic and semi-automatic mills.

Land Use

Land is needed in rice mills for several purposes. One major use is for sun-drying of parboiled paddy mainly in Engelberg mills. The other is for storage of the main raw material, namely paddy as well as for the processed rice before these are disposed off. While the drying space accounts for the bulk of the value of land under the mills, this is more so for the *chatals* (70%) but still a sizeable 30% for the automatic mills. On the other hand, storage space is important for both *chatals* and automatic mills (25% or so for each). Such use raises the issue of opportunity cost of land as there is an alternative to sun-drying in automatic rice mills. Inclusion of such opportunity costs may narrow the gap between the automatic mills and *chatals* and major mills in terms of capital or establishment costs.

Characteristics of Labour Employment

Both men and women are employed in rice mills. While women are employed in large numbers in rice mills compared to that in other industries (except garments), men outnumber women. On the whole, about 38% of the labour force is women. They are employed most in drying and cleaning part of the process. They are also involved interestingly in the milling and polishing part of the process which are generally thought to be men's jobs. It is noted that auto mills employ more male workers compared to that in semi –auto and Engelberg mills or *chatals*. In semi–auto mills and *chatals*, highest participation of women is noted in the drying process (Table 2).

Table 2
Participation (%) of Workers in Different Rice Mills (Annual Average)

Stage of Milling Operation	Auto		Semi Auto		*Chatals*	
	Male	Female	Male	Female	Male	Female
Boiling	93.4	6.6	83.1	16.9	73.4	26.6
Drying	64.7	35.3	55.4	44.6	43.5	56.5
Milling	98.5	1.5	60.4	39.6	74.2	25.8
Cleaning	74.4	25.6	64.3	35.7	53.7	46.3
Polishing	98.7	1.3	62.2	37.8	68.2	31.8

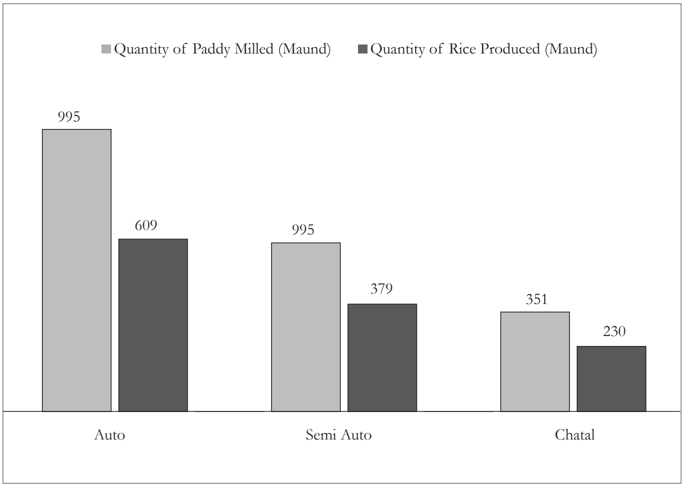
Rice mills use both temporary and permanent staffs. The number of permanent staff in automatic mills is roughly twice that in *chatals* and 60% more than in semi-autos. The differences are also unsurprisingly reflected in the capital/labour (value of capital/cost of labour) ratio which is 4.4 for automatic rice mills and it is 3 times higher than that in semi-auto mills and more than 17 times higher than that for *chatals*.

Operation by Shift

As has been mentioned earlier the milling of rice involves several processes. A full process is a shift. If a mill has several plants, several shifts in various stages may run together. In any case, the productive efficiency of the milling depends on how shifts are done. One major difference between auto mills and Engelberg is that as the latter is dependent mainly on sun- drying, it may take longer to complete a given shift, and more so during the rainy period. That is one reason why Engelberg hullers have low productivity. Given this, we find that it takes far longer (54 hours) in Engelberg compared to that in autos (only 14 hours) to complete a full shift from paddy to cleaned rice. Semi-autos take almost three times as much time (43 hours) to complete a shift as compared to the automatic mills.

On the other hand, the shift-wise milling capacity is far higher in the case of autos (Figure 4) compared to both semi-autos and Engelberg. Far shorter shifts and higher capacity per shift together raise the average productivity of autos compared to other types of mills in a given year.

Figure 4
Shift-wise Milling Capacity by Category of Mills



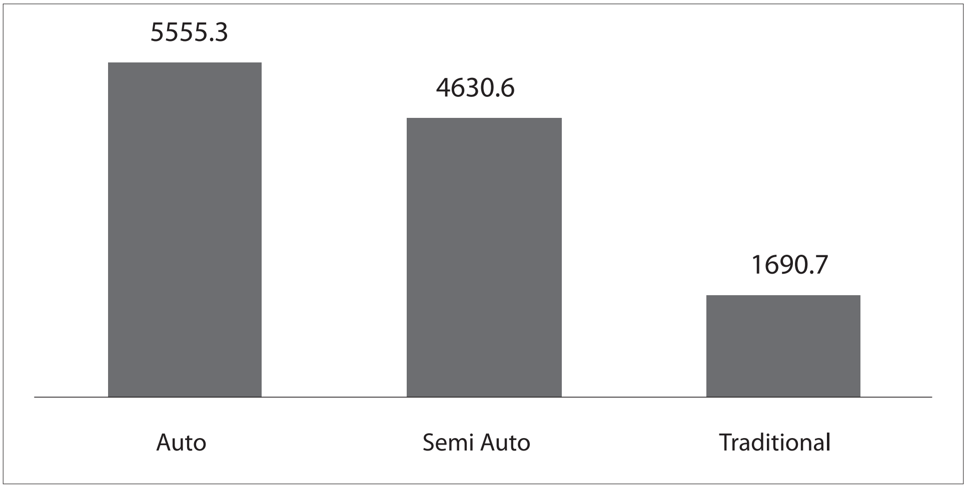
Average Productivity by Type of Mills

The mills can remain open throughout the year if there is enough supply of paddy. Especially, the auto mills can operate even during the rainy season. The semi –auto and *chatals* have to remain closed when sun-drying is hampered by rains. From the two figures above, it may be inferred that an auto mill can run at least one and a half shift (on an average) every day. Thus in a running week, it can mill (1.5 shifts X 609 maunds X 7 days) 6394 maunds (255,780 kg) of rice. In comparison, a semi auto mill will be able to run 4 shifts per week that will generate (4 X 379 maunds) 1516 maunds of rice, which is 4 times less than the production by auto mills.

Energy (Electricity) Consumption by Rice Mills

Average electricity consumption per shift of operation is presented in Figure 5. As *chatals* have lower capacities and also fewer electrically operated machineries, one finds that the electricity consumption per shift is highest in auto mills, which is 19 percent higher than that in semi –auto mills but 228 percent higher than traditional *chatals*. Comparing these findings with the milling capacity as discussed above, it is noted that electricity cost per maund of milled rice is Tk 9, Tk 12, and Tk 7 for auto, semi-auto and traditional mills, respectively. Thus electricity cost is the lowest in traditional mills as many steps of the processing are done manually in this type of mills.

Figure 5
Average Electricity Consumption per Shift by Rice Mills (in Taka)



Price of Paddy and Rice

There is some difference among the mills regarding what prices they pay for paddy, the main raw material, and receive for rice, the main output. In general, autos pay somewhat higher prices on average for the paddy they procure and sell the rice at somewhat higher prices compared to other types of mills. For paddy auto mills pay about 14/15 percent more compared to others for paddy and receive roughly similarly higher price for rice. It is known that automatic rice mills try to ensure steady supply for their milling operations as they make heavy investments, and for this, they offer farmers the highest seasonal price even if actual procurement is during a different season and also keep larger stocks of paddy for continuous operation. On the other hand, cleaned, polished and colour sorted rice may generally fetch a premium price.

Productivity of Rice Mills

The average productivity of rice mills in terms of processing capacity that is utilised shows a tremendous difference. Automatic rice mills do process 11-12 times as much as a *chatal,* while compared to semi-autos; the processing capacity is at least four times higher. These are absolute productivity differentials. Before examining whether relative productivities are different as well, we further analyse the issue of capital intensity.

The value of capital employed by automatic rice mills as well as the capital/labour ratios are much higher for automatic rice mills than in other types of mills. Such mills are also able to borrow more than others. Initially capital acquisition financed from borrowed sources was not much (34% for autos, 5% for semi autos, and 24% for *chatals*). Later the percentage of borrowing has increased to 55% for autos, 22% for semi autos, and 39% for *chatals*. Note that, the highest percentage is for auto mills. What all these mean is that capital-intensity though high in case of automatic mills, capital is less scarce for them. On the other hand, higher capital intensity and use of sophisticated machineries in automatic rice mills demand skilled labour which is relatively scarce. Thus, automatic rice mills may wish to realise higher productivity for labour compared to that for capital. And that is exactly what has been observed.

We now examine Table 3 which shows several indicators of productivity based on gross revenue. The first point to note here is that the ratio of gross revenue to capital is the lowest i.e. 5.9, for automatic rice mills which is nearly three times in case of semi-autos and more than nine times in case of *chatals*. The revenue/wage ratio, however, shows a different picture. In this case, autos have the highest ratio followed closely by semi-autos, but is trailed far behind by *chatals* at less than 15. These are classic examples of capital-intensive (or labour scarce) firms trying to maximise revenue per unit of labour cost and the labour-intensive (or capital-scarce) ones trying to maximise returns per unit of capital.

The productivity of labour in the first case is presumably higher and thus they get higher wage than in other cases where consequently they get lower wages (Table 3, last column). Note that, the automatic mills employ various kinds of advanced machineries which need more skilled labour than in other mills employing comparatively less sophisticated machineries and also manual operations which also explains the higher wages in case of automatic rice mills compared to the others.

The picture in case of net revenue is essentially the same as autos sell their rice more or less at the same but somewhat higher price than semi-autos and *chatals*. The slight price edge (12-15%) may be due to better polishing and whiter kernels than in other cases.

By associating productivity of various rice mills with the number of mills in 2011, it is noted that much of the rice in Bangladesh is still milled in the traditional *chatals*. While 78% of the rice is milled in this category of rice mills, the contribution of auto mills is 20% of the total supply of rice. Thus the idea that auto mills having the market power to manipulate price may not be substantiated based on such information if the average picture is considered.

Table 3
Selected Indicators of Relative Productivity

Mill Type	Capital/ Wage	Revenue/ Capital	Revenue/ Wage	Revenue/ Output	Revenue/ Labour (Tk)	Perm. Labour (Tk)	Unit cost of Perm. Labour
Auto	4.4	5.9	26.1	592.4	2879151	68	75,404
Semi Auto	1.5	16.5	24.6	513.4	979924	45	17,905
Chatal	0.25	57.0	14.6	526.9	463939	36	11,392

Note: Except shown explicitly all are ratios (number)

Aggregate Efficiency by Type of Rice Mills

Some estimates of the productivity differentials among the three types for rice mills have been discussed. These, however, do not take the use of aggregate inputs into consideration nor if the productivity is close to the theoretical maximum. For this, we discuss some of the estimates of technical efficiency as

Table 4
Efficiency Scores for Rice Mills

Category	Mean	Standard Deviation	Minimum	Maximum
Auto Mill	0.57	0.3	0.13	0.99
Semi Auto Mill	0.76	0.18	0.18	0.99
Traditional Mill	0.77	0.15	0.24	0.94

Source: Asaduzzaman *et al.* (2013)

reported by Asaduzzaman *et al.* (2013). These estimates are based on the maximum likelihood method for a stochastic frontier analysis. Here the technical efficiency is measured as the ratio between actual output and the potential output.[1]

Asaduzzaman *et al.* (2013) results are reproduced in Table 4. Efficiency scores range from 0 to 1. A value closer to 1 means that the mill is running very efficiently and divergence from 1 towards 0 indicates that the mill is inefficient in its operation as in the first case the theoretical potential output is largely realised while in the second the realisation level is much lower.

The table indicates that semi auto and traditional mills are doing better on average than auto mills in average efficiency score measure. On the other hand, the spread of the efficiency score shows that there is a wide variation among mills within its own category, yet, based on the standard deviation, the variation is more in case of auto rie mills. There may be several reasons for such differences among the types of rice mills.

While the establishment cost of auto mills is huge compared to that of the other two, these are comparatively recent and need more of skilled labour. The operation of the technology is not probably yet mature enough. For others that employ much less capital and less sophisticated machineries run with probably lower skilled labour which is probably more abundant, the operation is far more mature. It will thus take a considerable period of time for the auto mills as against others to increase the average score of efficiency.

Summary and Conclusions

Several summary points may be made. Automatic rice mills have come into the picture with increased demand for faster milling capacity. This is a comparatively recent phenomenon. Auto mills are highly capital intensive, employ various types of sophisticated technologies, can do much faster processing due to automated processes not dependent on weather factors, particularly for drying parboiled paddy, the average processing capacity is much higher while the cost of processing per unit are not greatly different. Over-all automatic rice mills may account for perhaps 2-3% of all mills, but they process some 20% of the total paddy. Such figures do not indicate oligopolistic behaviour in the aggregate but if only urban supply of rice is considered, this may probably have destabilising influence.

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[1] For an introduction to stochastic frontier analysis see Kumbhakar and Lovell (2000).

On the other hand, operations of automatic mills have several interesting implications for consumption, trading of rice, employment generation, land use, electricity consumption and on food security. On one hand, concerns over poverty mostly relate to ensuring food security, while on the other hand, food security is very much indicated by security in terms of the main staple, which is rice in case of Bangladesh. The faster and greater capacity of auto rice mills do ensure steady supply of milled rice to the market and in that sense; it helps in ensuring availability of the main staple. But automatic rice mills employ very high cost capital machineries which probably are not absolutely necessary from food security point of view. Colour sorters and polishers are two examples. Colour sorters do not add any value in terms of supply or quality except in terms of aesthetics, if at all. Polishers may create adverse nutritional implication by removing nutritionally useful components from rice.

Then again there is the issue of efficiency. In the aggregate analysis, automatic rice mills are far less efficient than the traditional ones and are thus wasteful. But this is likely to be transient phenomenon. As automatic rice mills become more mature in their operations, they may be more efficient in using their inputs to attain as close to the theoretical maximum output as possible.

Based on the above facts, the following policy conclusions may be drawn from the study:

The changing structure of rice milling needs to be matched with food security concerns of the government policy making. Therefore, use of colour sorters and polishers may be discouraged by imposing duties on import of such machineries and thus auto mills should be encouraged more to produce rice with better nutritional value. This will also improve the efficiency of the auto mills by improving the value for money in their operation.

Huge investment (for higher processing capacity) made by the auto millers and their need for keeping large stocks of paddy for ensuring round the year processing activity together with existence of limited number of such mills may give them some leverage in terms of market power. However, this is not the main issue in the case of increase of the price of rice; rather the mismatch in the supply and demand for paddy by these mills, transportation cost, limited use of mechanised dryers by non-auto mills and unnecessary use of polishing and colour sorting by auto mills increases the cost of rice processing and thus supply at higher price while limiting competition between traditional and auto mills.

Careful government initiatives are required to ensure that auto mills are able to maintain regular flow of paddy to utilise their capacity but not exercise their market power to raise price. In this connection, timely procurement of rice by the government under its PFDS system can play an important role. Moreover, open market sale of rice by the government and raising awareness among people regarding the lower level of nutritional value of very white polished rice could be fruitful strategies. To discourage production and consumption of white rice, government may consider procuring only non-polished rice or may give a premium price to that. It may discourage the use of colour sorters and polishers while encouraging drying machineries and foster competition between auto mills and the traditional *chatals* and semi-auto mills through proper fiscal policies.

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Chapter 12

Solar Energy in Rural Mechanisation: The Case of Solar Pumping for Irrigation in Bangladesh[1]

Nazmun Nahar

Introduction

In Bangladesh, 8% of deep tube wells, 83% of shallow tube wells and 94% of low-lift pumps used for irrigation are run by diesel (BADC, 2013). While diesel power is by far the dominant source for irrigation, there are concerns that pumping irrigation water using diesel fuel is expensive and is likely to increase due to rising diesel price in future. Additionally, the level of the subsidy provided by the government will also increase as a continuation of support to irrigation by farmers.

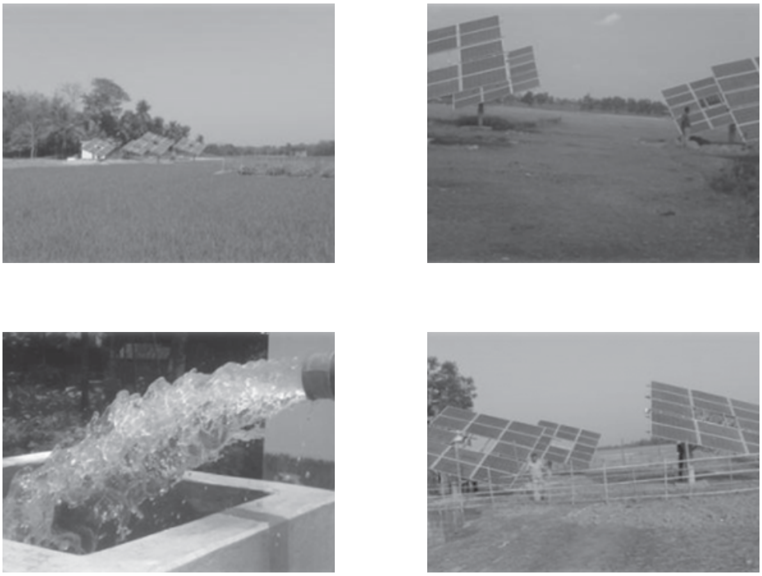
Currently, government is providing huge subsidy to about 1.5 million million diesel operated pumps, which is a significant pressure on national economy and creates huge financial burden. As an alternative to expensive diesel-dependent irrigation system, the use of solar power to replace diesel powered irrigation is now a tested and proven solution. To release huge financial burden of government to provide direct and indirect subsidy in diesel based irrigation, solar pump solution can be the best alternative with other socio-environmental benefits i.e., local air quality improvement, reduction of green house gas etc. Solar powered irrigation systems are well established and they have proved a reliable and problem-free alternative to conventional diesel powered irrigation systems. It has already been tested and commercially rolled out in many countries like India, Pakistan, Uganda, etc. In India, solar pumps are running successfully transforming lives of thousands of rural farmers. The technology is matured and the systems have proven that they can withstand the weather conditions in Bangladesh. Their superiority to conventional

[1] This is a revised shortened version of the paper presented at the Regional Workshop on Rural Mechanisation at the BRAC Centre Inn, Dhaka on 7-8 March 2013.

systems lies not only in the economics but also in pollution abatement. The technical feasibility of solar power irrigation systems has been well established, while economic feasibility has been a major barrier restricting wide spread use in Bangladesh. Solar energy powered systems usually require a substantial initial investment as compared to conventional power system, which makes them very sensitive and vulnerable to economic environment. However, since solar powered systems usually have life span of about 25 years and the conventional system has a life span of about only 5-7 years, there is room for comparison. The approach here is usually to compare the long run energy cost per annum of the solar system with that of the conventional system taking into account initial capital investment, running costs, maintenance cost, and fuel cost.

Figure 1

Solar Pumping for Irrigation



Power generation using solar PV system is pollution free, but when there is question of storing the energy then we have to think about environment pollution by batteries. Solar Irrigation System (SIS) gives us strength to generate pollution free power and consume power without polluting our environment because Structural Insulated Panels (SIPS) offer a system without battery.

Long Term National Advantages

A pumping system comprises of the pump, a motor, solar modules, a control device and piping accessories. When sunshine strikes on the solar panels, it produces DC electricity. DC electricity either drives a DC motor or is

Table 1
Solar Versus Diesel Pump

Aspects	**Conventional Pump (D/E)**	**Solar Pump**
Flexibility in use	Flexible as surface pump, limited to 23 feet TDH	Can be used in both surface and submersible water sources.
Ownership	Middleman owned, farmers rents the pump/subscribe	Community owned
Electricity demand	1400MW in irrigation season (from 2,66,000 Electric pumps only)	
Operation and maintenance	High operational and maintenance cost and time	Minimal operation cost & time.
Environmental compatibility	Emits 9,100 K-Ton CO_2 per year! (from 13,00,000 Diesel pumps)	Zero emission
Manpower requirement	High manual operation, requiring more labours	Minimal labours, resulting from fully automatic operation
Engine Life	2-5 years	10 years
Fuel carriage	Frequent hassle in fuel carriage	Uses abundant sunshine as fuel
Servicing and overhauling	Servicing frequency: 3-5 times per year, overhauling: once a year	Cleaning and dusting only
Water misuse	Accompanied with open drain with huge water loss with deep percolation and evaporation	Accompanied with PVC buried pipe network to minimise water loss.
Efficiency	Poorly efficient	Highly efficient (Motor efficiency up to 92%)

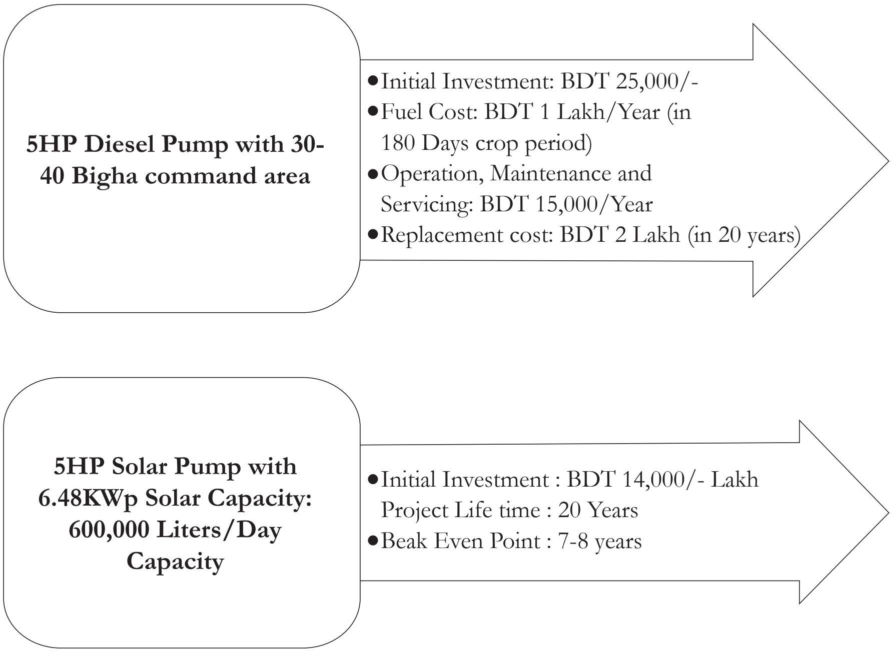
converted to AC by inverter and propels an AC motor. AC/DC motor is coupled with a pumping element (centrifugal or helical rotor), which draws water from surface/submersible water source. Specially made Maximum Power Point Tracking (MPPT) controller enables the systems to lift water even in diffused sunlight (cloudy or foggy days). The relative advantages of solar irrigation pumps are presented in Table 1.

Case Study for Economic Compatibility

Figure 2

Solar Pump Versus Diesel Pump for 12 years

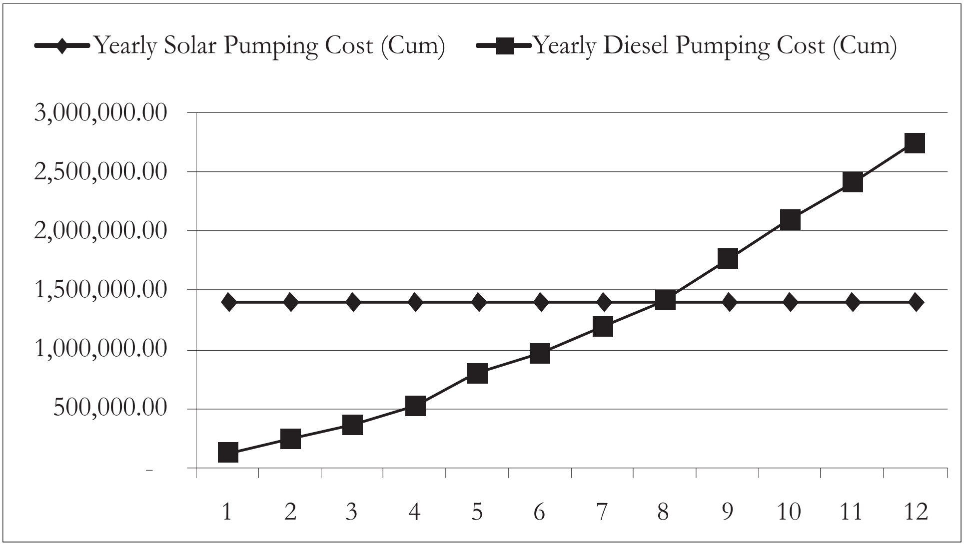
Note: These cost estimates and calcutations throughout this paper are based on prices in 2012 - 2013.



Road Map

Incidentally, very few significant initiatives except couple of government agencies demonstration projects are so far evident to bring partially cropped but agriculturally potential lands into three crops cycle.

Figure 3
Comparative Costs of Diesel Versus Solar Pumping



To bring significant changes in our long practiced diesel based irrigation, solar irrigation installations need to be escalated. It needs budgetary provision in the national budget to roll out those projects through its relevant agencies. A tentative installation road map is proposed below with annual target with an aim to achieve tangible national benefit worth BDT 2509 million over a 10-year period.

Assumptions

If 10% of total diesel operated pumps are replaced by solar pumps, diesel worth of BDT 5602 million will be saved every year (for an idea about petroleum import cost, see BPC (2011). This is likely to save BDT 14566 million direct subsidy per year.

Rationale

In terms of replacement opportunity, assuming 1.32 million shallow diesel pumps in action, 10% is a reasonable number to start with. By rolling 13,200 pumps, relevant organisation involved in the roll out programme will gain invaluable experience to mitigate implementation problems and be able to set management and monitoring standard.

Enabling environment requirement for such 10% transformation

- 10 years roll out time
- Motivational subsidy starting from 50% to encourage farmers for technology adaptation, attractiveness over existing diesel rate, encouraging private party involvement, community engagement, and speedy rollout.
- Gradual phase out of subsidy to 0% can be implemented by the 10th year due to technological awareness, commercial viability (over diesel pump life cycle with fuel price hike), sustainable development.

Project component: cost of single installation of SIS

- Project cost: BDT 1800,000(USD 22,500)
- Capacity: 500000 liters/day (@15~20 feet TDH)
- Buried pipe network for loss minimisation: BDT 460,000 (USD 5750)
- Project command area: 60 *bigha* for rice; 80~90 *bighas* for cash crop.
- Project cost @50% grant: 11,30,000 (USD 14,125)

Solar Irrigation Project Rollout Road Map for 20 Years

Table 2
Costs of the Road Map

Fiscal Year	Number of Installations	Project Cost (million BDT)	Proposed Grant (%)	Grant Requirement (million BDT)
2013-14	300	678	50%	339
2014-15	300	678	40%	271.2
2015-16	500	1130	30%	339
2016-17	1000	2260	25%	565
2017-18	1000	2260	25%	565
2018-19	1200	2712	25%	678
2019-20	2000	4520	20%	904
2020-21	2200	4972	15%	745.8
2021-22	2200	4972	10%	497.2
2022-23	2500	5650	0%	0
Sum Total	**13,200.00**	**29832**		**4904.2**

Table 3
Benefits of the Road Map

Fiscal Year	Number of Installations	Yearly Subsidy Saving (million BDT)	Yearly diesel Saving (Ltr)
2013-14	300	8.775	540,000
2014-15	300	19.305	1,080,000
2015-16	500	38.93	1,980,000
2016-17	1000	81.76	3,780,000
2017-18	1000	132.76	5,580,000
2018-19	1200	184.15	7,740,000
2019-20	2000	296.78	11,340,000
2020-21	2200	440.45	15,300,000
2021-22	2200	554.45	19,260,000
2022-23	2500	752.40	23,760,000
Sum Total	**13,200.00**	**2509.76**	**90,360,000**

Proposed Project Framework and Roles of Parties

To scale up solar irrigation usage at grass root level, recent solar demonstration/pilot projects undertaken by the GoB agencies like BADC/REB need to be escalated. BADC and REB are already equipped with experience of rolling out of solar irrigation pumps at different locations of the country and initial responses they have achieved are satisfactory.

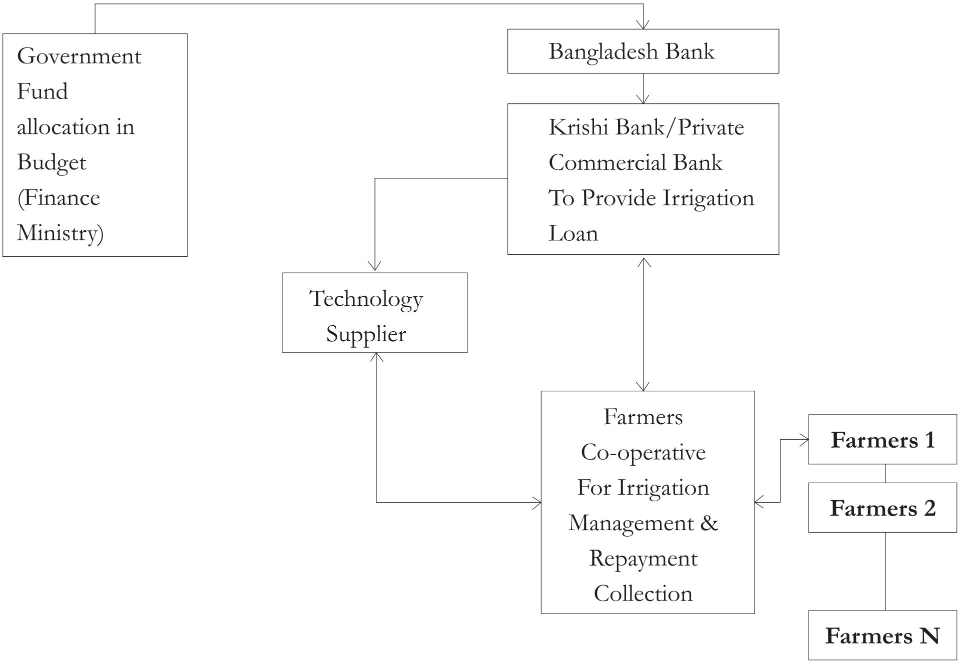
The proposed execution model has been designed with a provision to engage farmers/farmers co-operatives to even implement the solar irrigation project by them taking soft financing support from GoB. Krishi Bank or any other commercial bank that has access to development partners fund.

Implementing Plan

Modality : A

50% initial grant from GoB and farmers contribution up to 50%, via government/commercial banks. The proposed framework is given below :

Figure 4
Implementing Plan – Modality : A



Each pump can be distributed to farmers/farmers community under the following financing propositions:

Grant: 50% on capital cost for installation

Soft Loan: up to 40% with a tentative interest rate of 5~6%

Equity/participation of Farmers/Farmers Co-operative**:** 10% as down payment or in suitable installment, if project is implemented under the supervision of government agencies.

A brief financial analysis has been developed with realistic assumption on solar irrigation project as follows:

Table 4
Realistic Assumption on Solar Irrigation Project

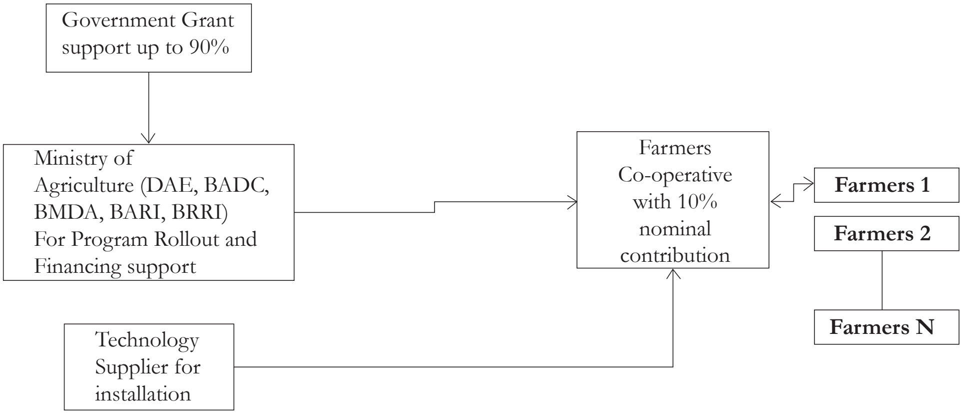
13,200 Nos. 5 Hp Solar Pumps	**Key Indicators/assumptions**	**Results/Considerations'000**
1	Solar pump economic life	20 years
2	Estimated fund requirement	BDT 298.32 *Lakh*
3	Grant	50% equivalent to 149.16 *Lakh*
4	Soft financing	40% equivalent To 119.33 *Lakh* @5% interest rate
5	Sponsors equity	10% equivalent to 29.83 *Lakh*
6	Diesel saved worth (Considering current selling price)	BDT 56.02 *Lakh* over 10 years project time
7	Diesel subsidy in the project life to be offsetted (Considering current selling price)	BDT 25.09 *Lakh* over 10 years project time
8	Productivity increase due to multiple crop cultivation	Equivalent to 792 tonnes rice
9	Project payback	Less than six years
10	Project outcome	Transfer of full ownership of pumps to farmers/farmers community after repayment

Modality: B

BADC or similar organisations can operate SIS with a provision of 90% initial grant (and 10% token handover fee) to exemplify project case among the communities. The proposed framework is given below:

Figure 5

Implementing Plan – Modality : B



In this arrangement, GoB has to provide up to 90% initial grant in implementing SIS project by taking nominal contribution from farmers through cooperatives. This can also be implemented as per existing BADC deep tube well programme/LLP programme. The roles of the above proposed model are self- explanatory.

Recommendations for Way Forward

Government Policy Support

- Community loan policy from Krishi Bank, Sonali Bank or other state owned bank.
- Motivational subsidy on purchase of solar pumps.
- Bulk replication of BADC, REB, BARI, BMDA, RDA, etc. trial projects.
- Import duty exemption on all solar pump equipments.
- Gradually injecting cash subsidies to solar pump from diesel subsidies to promote solar.
- Technical governance through regulatory body for product standardisation, R&D, testing, etc.

Private Policy Support

Commercial banks, along with state-owned banks, can provide preferential loan facilities to the entrepreneurs for promoting solar irrigation pump system.

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Bangladesh Agricultural Development Corporation (BADC) (2013). Minor Irrigation Survey Report 2012-13. Ministry of Agriculture, Government of the People's Republic of Bangladesh, 2013.

Chapter 13

Food Processing: New Avenues for Rural Entrepreneurship and Nutrition Security in India? A Note

N. G. Shah

Introduction

The policy makers and executing agencies are struggling to address food and nutrition security in India. On the one hand the national agro-food production data indicates self-sufficiency to fulfill the needs of population at large, while on the other hand one sees the issues of malnutrition. Around 47 % of the children have some degree of malnutrition in Asian countries and the presence of malnutrition is felt across tribal, rural as well as urban parts of the country.

Context

Most of the malnutrition sets in during the first two years of life and the damage caused is largely irreversible because physical growth is retarded for life and permanent damage is caused to the brain. As a result, the children have lower intelligence, lower education, lower strength and stamina, lower productivity and lower income. Health professionals suggest that the quantity of food, nature and density of nutrients and the feeding frequency must be carefully adjusted to meet the needs of growing child.

In majority of the developing countries over 25% of fresh products from agriculture (mainly fruits and vegetables) are lost due to inadequate post harvest techniques employed and lack of processing, distribution and supply chain management in the food processing sector. In this backdrop the food processing entrepreneurship can contribute in a significant manner to ensure nutritional security of the large population which is deprived of recommended healthy diet by the nutrition experts. To cite an example, global experience shows that 1 percent increase in packaging results in 1.6% decrease in wastage.

Food processing can help reduce this waste and enhance the country's nutritional security. There is a need to develop appropriate food processing technologies to improve efficiency of the existing manufacturing systems and/or to develop new processes. Three main objectives of improved food processing are: (i) enhancing nutritional security (ii) possible increase in farmers' income and (iii) providing livelihood opportunity in rural areas. Two case studies illustrate benefits of food processing with nutrition focus.[1]

Case 1

Production methodology in making nutrition therapeutic foods from locally available ingredients such as peanuts, milk powder, sugar and vegetable oil. It involves a production process that includes a series of operations in sequence i.e. dehusking peanuts- roasting- grinding- peanut paste- mixing with sugar, milk powder, vegetable oil and micronutrients- finish grinding- packaging.

Demonstrative "Production unit" was set-up at a municipal hospital in Mumbai to make Medical Nutrition Therapeutic (MNT) with the following ingredients:(peanut butter 25%, vegetable oil-soybean 21%, skimmed milk powder 24%, powdered sugar 28%, and micronutrient mix 2%).

Case 2

A supply chain for farm produces from small farmers facilitated by a "Farmers Club" (Co-operative institution concept). Flow of various activities of Abhinav farmers' club, Pune, India involved steps as follows:[2] Order capture follows order consolidation assignment to farms, which then leads to production planning and supply control; product goes to packaging centre, which after order completion payment transfer are processed for delivery.

Challenges

Some of the major challenges for the food industry in India are:

i. Backward/forward integration from the farm to the consumers;

ii. Development of marketing channels;

[1] An on-going PhD work of a student at IIT-Bombay addresses sustainability of small-farming systems. The question asked is what is being sustained (i.e. cropping pattern, productivity, land areas, small farmers themselves). It involves a survey of 98 farmers growing rice, sugarcane and mango.

[2] A lesson learned is a tie-up with farmers' club (a co-op) for marketing of products / supply chain systems or associated small-scale industry can increase sustenance of small farmers in marketplace. This is demonstrated through this case study.

iii. Development of linkages between industry, government and institutions;

iv. Taxation in line with other nations and streamlining of food laws.

Conclusions

i. There is a growing opportunity in India to stimulate and support growth of the food processing industry.

ii. Taking care of the domestic demand for processed foods through R&D efforts can help "Nutrition Security".

iii. "Inclusive growth and Sustenance" of small producers requires the development of associations, cooperatives or clusters that make it easier for small producers to articulate, lobby for their interests and reach processors and consumers.

Chapter 14

Mechanisation of Agriculture in Bangladesh– Glimpses from the German Perspective

Matthias Kleinke

Introduction

The economy of Bangladesh has changed dramatically in recent years. From a largely agricultural economy, it has transformed itself more and more into an industrial and service economy. The traditionally well-developed sector of agriculture is now only less than one fifth of the country's GDP. There is a significant growth in importance of the industrial sector and the service sector. Nevertheless, still three out of five people in Bangladesh are working in the agricultural sector. Especially for the rural population, about three quarters of the total population, the agricultural production is the most important way to make a living. To realise a sustainable and socially equitable agricultural development, Bangladesh likes to preserve the small-structured farms in agriculture and so as to give many people the opportunity to earn their living by working in agriculture.

This effort, which stands in a big contrast to rural development in Europe during the last decades, holds many chances for the country and has a great influence on the development of agricultural mechanisation. Among the achievements that could be reached by the country in recent years - thus the needs of the population are now covered by rice grown from own cultivation - the mechanisation of agriculture has contributed to a significant extent. The amount of engine powered machines increased dramatically during the last two decades. Especially the use of irrigation technology, but also the ever-increasing use of motorised tillage equipment, the prevention of post-harvest losses and improved transportation has in addition to the establishment of new crop varieties contributing to the increasing yields in Bangladesh. There have been significant developments but also in the horticultural sector, animal husbandry and aquaculture caused by the higher level of mechanisation.

Issues in Mechanisation

The machines used on small-scale agricultural land have to be adapted to these conditions. They should be easy to use, light and robust and, above all, inexpensive. This applies to all kinds of rural machinery. Especially the use of Chinese agricultural machines in Bangladesh is therefore very popular.

Although the structural development in China has taken another development in the field of agriculture the Chinese agricultural machinery industry produces machines which are adapted for use in Bangladesh and meet the attributes above. Simply designed, small diesel and gasoline engines that are used in various applications play an important role here. They are used e.g., in pumps, tractors, threshers, shellers and mills. Even though these machines in terms of both precision and energy efficiency are not always corresponding to the latest developments, they have many advantages. The products of European agricultural machinery manufacturers are mainly designed for a completely different agricultural structure and are often too expensive. To develop own technical solutions in the agricultural technical institutes of Bangladesh will play an important role in the adapted mechanisation of the country.

Particularly remarkable is that in cooperation with international partners, the first projects of a modern use of renewable energy in agriculture are established now in Bangladesh. Especially the use of solar energy - but also the energy use of surplus biomass has great potential in rural areas of Bangladesh. This makes it possible to avoid CO_2 emissions from fossil fuels. An important question, however, is the economic viability of such solutions. Against the background of rising energy and commodity prices on the world market, the prospects are here, however, extremely favourable.

The objective to sustain and support the small-scale mechanisation in agriculture represents a great challenge. Just the good performance in the field of industry and services will encourage movement of the population into the urban areas. Whether it is possible to create sufficiently good prospects and development for people in their rural home remains to be seen. From the perspective of economic and social development throughout rural Bangladesh that would be very desirable.

Conclusions

The workshop “Rural Mechanisation: Policy and Technology Lessons from Bangladesh and other Asian Countries” in Dhaka presented a very good opportunity to start a conversation with partners in Bangladesh and learn more about the interesting developments in the field of mechanisation of agriculture there. Through the participation of representatives from neighboring countries in the region similarities and differences as well as future perspectives could be discussed.

From the perspective of a German scientist, there are many opportunities for cooperation in the scientific field, especially in the field of energy efficiency and renewable energy use in rural areas, the German experiences should be a benefit. Also the research field of low-emission and environmentally friendly sustainable agriculture offers many opportunities for meaningful joint research and development projects.

Rural Mechanisation: A Driver in Agricultural Change and Rural Development

Reflections on Rural Mechanisation

Excerpts of selected comments from the Regional Workshop on 'Rural Mechanisation: Policy and Technology Lessons from Bangladesh and Other Asian Countries', held at the BRAC Centre Inn, Mahakhali, Dhaka on 7-8 March 2013.

From left: Dr. M.A.Sattar Mandal, Member (Agriculture) of the Planning Commission; Matia Chowdhury, Minister for Agriculture, Government of the People's Republic of Bangladesh; Atiur Rahman, Governor of the Bangladesh Bank; and Dr. Mahabub Hossain, Executive Director of BRAC.

Matia Chowdhury, *Minister for Agriculture, Government of the People's Republic of Bangladesh.*

Mechanisation is a must and there is a huge demand for such technologies in the local farm sector. Agricultural machinery manufacturers should recognise farmers' needs to promote mechanisation in the farm sector and they should introduce machines that are affordable by the vast majority of the country's small and marginal farmers.

Mechanisation is the prime need to address the scarcity of farm labour and rising wage rates in peak seasons of crop operations, but the manufacturers and importers must not get involved in any 'push- sales' of machines that are not suitable for farmers. Small and marginal farmers need small technologies. As almost all of the country's agricultural land is privately owned and operated, the government can only promote technologies that farmers want, government cannot impose anything on them. Government has been promoting appropriate type of machinery through modest subsidy, field demonstration and farmers' training programmes through the national agricultural services across the country. Government also encourages and supports the private sector in delivering appropriate machines according to farmers' needs and choices.

Dr. Atiur Rahman, *Governor, Bangladesh Bank*

Agriculture played a major role in helping the economy evade the adverse impacts of the global financial crisis. Bangladesh Bank has expanded agricultural credit facilities with special focus on small holders and introduced sharecropper's credit programme as well as SME loans to support mechanisation programme of the government. This has resulted in raising farm productivity substantially.

Dr. Mahabub Hossain, *Executive Director, BRAC*

Tightening of the agricultural labour market and a rise in wage rates provided incentives to farmers to go for labour- saving agricultural operations. As a result, a market for selling various types of machine services developed in the country side.

Dr. M. A. Sattar Mandal, *Member (Agriculture), Bangladesh Planning Commission*

Liberal machinery import policy in the past was a key driver in encouraging expansion of farm machinery in Bangladesh agriculture; local manufacturing of machinery spareparts has expanded, but it needs upscaling of skills and quality of machines to give greater value for money invested by the farmers.

Dr. Shamsul Alam, *Member (General Economics Division), Bangladesh Planning Commission*

Farm mechanisation/ tractorisation would help meet up seasonal shortage of labour and overcome and/or release labour for diverse crops in critical periods of farm operations, which should result in higher total farm productivity. More investment is needed for R&D to make machinery more scale- neutral.

Dr. Wais Kabir, *Chairman, Bangladesh Agricultural Research Council*

Agricultural mechanisation is the demand of the time in Bangladesh when labour shortage is becoming increasingly evident in the rural areas. Mechanisation has become a tool for increasing efficiency and reducing cost of production in agriculture. Government policy support, research as well as extension programmes favoured expansion of farm machinery.

Dr. Stephen D. Biggs, *Research Fellow, University of East Anglia, UK.*

Overall government energy policy is central to influencing future patterns of rural mechanisation and strategies of agriculture and rural development, as availability and lower prices of electricity and fuel have played a key role so far in spreading mechanisation in many parts of Asia.

Scott E. Justice, *Rural Mechanisation and Development Specialist, CYMMIT, Nepal*

The great increase in the range and diversity of engines (energy and power) and other equipment available in Bangladesh and international markets, has drawn attention and imagination of academic, commercial, donor and other interest groups for the promotion of particular new mechanisation technologies.

Pictures of Farm Equipment

STW in Bangladesh

Plastic Lay Pipe in Nepal

4W Tractor in Bangladesh

Battery Operated Cycle Van in Bangladesh

Mini Tillers in Nepal

Mini-Tillers & Animal Puddling:
Courtesy- Peter Lowe, USAID, Nepal

Dryland Tillage in Bangladesh

Power Tiller Operated Seeder in Bangladesh

Tractor Haulage in Odisha, India

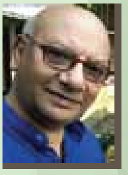
Walk Behind Reaper in Bangladesh

Power Thresher in Bangladesh

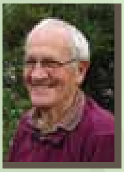
Electrically Run Thresher in Odisha, India.

Courtesy : Scott Justice (CIMMYT) ; Sattar Mandal (BAU/FAO); Peter Lowe (US AID, Nepal); M.A. Matin (BARI/CIMMYT).

Index



M. A. Sattar Mandal, a Professor of Agricultural Economics, is currently affiliated as a Senior Advisor to Food and Agriculture Organization of the United Nations (FAO) in Bangladesh. He has bachelor and master degrees in Agricultural Economics from the Bangladesh Agricultural University (BAU), Mymensingh, a PhD from the University of London, and a post-doc study from the University of Oxford. He spent over four decades of teaching and research in agricultural and rural economic development, policy planning, and technology development. He was the Vice- Chancellor of BAU, two-term Member of Planning Commission (General Economics, and Agriculture). He is involved as a guest Professor at the Rhine-Waal University of Applied Sciences, Kleve, Germany.



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Scott E. Justice is a Rural Mechanisation and Development Specialist of CIMMYT, Nepal. He has a BA in Political Science, an MA in Anthropology, and a Graduate Certificate in Environmental Systems, all from the University of Kentucky, USA. He has been working on agricultural and rural mechanisation research and development issues in South Asia, East Asia and Africa in both technical and socioeconomic arenas for over 20 years.

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ISBN: 978-984-34-2253-8