



# Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings



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## ABSTRACT

There is strong advocacy for agricultural machinery appropriate for smallholder farmers in South Asia. Such 'scale-appropriate' machinery can increase returns to land and labour, although the still substantial capital investment required can preclude smallholder ownership. Increasing machinery demand has resulted in relatively well-developed markets for rental services for tillage, irrigation, and post-harvest operations. Many smallholders thereby access agricultural machinery that may have otherwise been cost prohibitive to purchase through fee-for-service arrangements, though opportunity for expansion remains. To more effectively facilitate the development and investment in scale-appropriate machinery, there is a need to better understand the factors associated with agricultural machinery purchases and service provision. This paper first reviews Bangladesh's historical policy environment that facilitated the development of agricultural machinery markets. It then uses recent Bangladesh census data from 814,058 farm households to identify variables associated with the adoption of the most common smallholder agricultural machinery – irrigation pumps, threshers, and power tillers (mainly driven by two-wheel tractors). Multinomial probit model results indicate that machinery ownership is positively associated with household assets, credit availability, electrification, and road density. These findings suggest that donors and policy makers should focus not only on short-term projects to boost machinery adoption. Rather, sustained emphasis on improving physical and civil infrastructure and services, as well as assuring credit availability, is also necessary to create an enabling environment in which the adoption of scale-appropriate farm machinery is most likely.

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## 1. Introduction

By 2050, global population is expected to reach 9.6 billion (Gerland et al., 2014). As a result, the consumption of staple cereals, including rice, wheat, maize, as well as fish and meat products is expected to increase dramatically – particularly in rapidly developing countries (Godfray and Garnett, 2014). To ensure cereal food security alone in 2050, more than a doubling of production is required (Tilman et al., 2011). This situation is complicated by the anticipated strain on global cropland availability, resulting in calls to intensify production on available land in order to avoid natural land conversion and biodiversity loss, while also working to reduce food waste and curb overly consumptive diets (Tilman et al., 2011).

These problems are particularly acute in densely populated South Asia, which records the highest number of extremely poor people living on less than USD 1.25 day<sup>-1</sup>, estimated at 399 million in 2011 (World Bank, 2015b). Over half of the population depend primarily on agriculture, and average farm sizes range from just 0.53 to 2.1 ha (Hossain et al., 2007; PBS, 2010). In 1961, per capita arable land in Bangladesh, India, Nepal, and Pakistan ranged between 0.17 and 0.36 ha, though by 2012, these figures shrunk to 0.12–0.24 ha. Agriculture is also a leading source of income and employment in rural areas. In 2005, for example, 48% of the total employed labour force in Bangladesh, 56% in India, 43% in Pakistan, and 66% in Nepal were directly involved in agriculture (World Bank, 2015a). Yet at the same time, rural to urban migration is increasing with the expansion of non-farm employment opportunities, causing seasonal rural labour shortages (Zhang et al., 2014).

Within this evolving context there has been strong advocacy for agricultural machinery appropriate for farmers' small fields and

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resource base, and to enhance land productivity and encourage sustained agricultural intensification (FAO, 2008; Kienzle et al., 2013). Such machinery may be of interest to smallholder farmers because of potential production cost savings and reduction in drudgery by substituting manual labour and traditional tools with efficient machineries (World Bank, 2007; Kienzle et al., 2013; Mahmud et al., 2014). Such 'scale-appropriate' agricultural machinery is also increasingly custom-designed to be suitable for farmers' small and fragmented landholdings, and to facilitate the conservation of agricultural resources (Krupnik et al., 2013, 2015; Baudron et al., 2015). For example, the practices of zero and strip tillage require specialized machinery and can reduce costs by saving fuel, time and irrigation water (Erenstein and Laxmi, 2008; Fileccia, 2009; Krupnik et al., 2014). For farmers using flood irrigation, machine-aided laser levelling can provide substantial water savings (Ahmad et al., 2001), reducing pressure on groundwater reserves and energy savings for pumping, thereby enhancing gross margins by up to USD 143.5 ha<sup>-1</sup> (Aryal et al., 2015; Magnan et al., 2015). But despite the resulting advocacy for 'scale-appropriate' mechanization, questions remain as to what factors are associated with smallholder adoption, with important implications for development programs promoting mechanization.

To respond to these questions, it is necessary to understand the characteristics of farm households that invest in farm machinery, both for their own use and to rent-out services to other farmers. This consideration is important, because in contrast to the predominant model of machinery ownership on larger-sized family farms in developed countries, in emerging economies like Bangladesh, relatively few farm households invest in their own agricultural machinery. Instead, increasing numbers of smallholder farmers' access agricultural machinery services through custom hiring arrangements (Biggs and Justice, 2015). Studying households that own machinery can provide insights into the factors that facilitate or limit such agricultural machinery investment choices, thereby aiding development planners and policy makers, including legislators who allocate public funds, as well as national and international banks to target investments more appropriately. We are however unaware of any recent studies that examine these issues at a large scale. Using Bangladesh as a case study, this paper fills this gap by identifying the factors associated with the adoption of some of the most common agricultural machineries utilized on farms, including irrigation pumps, threshers, and power tillers (used for mechanized tillage/land preparation, generally driven by a two-wheel tractor (2WT)), using census survey data.

This case is worth investigating for several reasons. The agricultural sector (excluding fisheries) contributes 12.64% of Bangladesh's GDP (GOB, 2015). Out of 54.1 million active labourers in Bangladesh, 25.6 million (47.3%) are engaged in agriculture (GOB, 2015). Yet evidence indicates a progressive shrinking of rural labour availability, as workers migrate to cities or abroad to engage in more remunerative employment, particularly in the garments and construction sectors (Zhang et al., 2014). Projections also indicate that rice and wheat production will need to increase by 0.4 and 2.17% year<sup>-1</sup>, to keep pace with the additional two million added to the population annually (Mainuddin and Kirby, 2015). At the same time, there is little scope to extend the agricultural land frontier: cropland availability in Bangladesh has declined by 68,760 ha year<sup>-1</sup> (0.73%) since 1976 (Hasan et al., 2013). In other words, Bangladesh needs to produce more food from the same land, while at the same time easing farm labour requirements resulting from the country's increasingly profitable alternative forms of employment (Zhang et al., 2014).

Appropriate farm mechanization has been emphasized as an important policy and development goal in Bangladesh (Mandal, 2002, 2014; Zhang et al., 2014). Compared to other South Asian

nations, farm machinery use has advanced considerably in Bangladesh (Justice and Biggs, 2013), particularly for land preparation, irrigation, and post-harvest activities. In 1996 there were only 0.1 million power tillers, 1.3 million pumps (including deep, shallow and surface water pumps), and 0.18 million rice-wheat threshers used in Bangladesh. By the early 2010s, these figures increased to at least 0.55 million power tillers (Ahmed, 2014), 1.61 million pumps (BBS, 2011; BADC, 2013), and 0.25 million threshers. Use of irrigation pumps has been a key ingredient in Bangladesh's current level of near rice self-sufficiency (Hossain, 2009; Mainuddin and Kirby, 2015). Study of Bangladesh could therefore provide important insights into the factors that affect the spread of scale-appropriate mechanization.

In this paper, we analyse the factors associated with agricultural machinery ownership in Bangladesh. Using farm household census data, we characterize rural farm households who invest in agricultural machinery, while also assessing the role of factors such as civil and institutional infrastructure and services. We begin with a brief review of the historical policy environment that facilitated the development of agricultural machinery markets in Bangladesh, particularly the growth of agricultural mechanization since the 1970s, focusing mainly on government policy liberalizing the farm machinery sector and its underwriting with subsidy programs. We subsequently describe the census data utilized, after which we specify our econometric models, present major findings, and explore policy implications for scale-appropriate agricultural mechanization.

## 2. Agricultural mechanization in Bangladesh

With the world's highest population density (of countries with a substantive landmass) and highest per-capita rice consumption (172.6 kg person<sup>-1</sup> year<sup>-1</sup>; FAOSTAT, 2015), the Government of Bangladesh (GOB) has historically encouraged agricultural intensification and mechanization as an avenue to increase production and move towards rice self-sufficiency (Mainuddin and Kirby, 2015). To facilitate this process, the GOB voluntarily reduced import restrictions and tariffs on select agricultural machineries, and developed subsidy programs to partially offset fixed costs for 2WTs, irrigation pumps, and threshers (GOB, 1999). Irrigation pumps were first introduced by the GOB in the 1960s (Ahmed, 2001). Their supply was later sustained by the private sector following the GOB's voluntary liberalization of the machinery market and relaxation of import tariffs from 1988 to 1995 (Hossain, 2009; Gisselquist et al., 2002).

The GOB also initially promoted four-wheel tractor based mechanized tillage, which is arguably scale-inappropriate given Bangladesh's average farm size of around 0.53 ha, which is usually further fragmented into multiple fields (Hossain et al., 2007). Such fragmentation makes demand aggregation for tillage services among farmers, and between field and farm transport difficult to achieve with larger tractors. The GOB also first introduced centralized irrigation facilities by establishing Deep Tube Wells (DTWs) and supplying surface water Low-Lift Pumps (LLPs) to farmers on a rental basis from the Bangladesh Agricultural Development Corporation (BADC), with fuel supplied at a 75% subsidized rate until the late 1970s (Hossain, 2009). By 1978, BADC had rented out and managed a total of 9000 DTWs and 35,000 LLPs (IDE, 2012).

Public irrigation management and use of larger tractors for land preparation, however presented large logistical and financial burdens. Eight years after independence in 1979, Bangladesh undertook liberalization policies, with the GOB gradually opting out of State-led mechanization support (Gisselquist et al., 2002). BADC initiated sales to liquidate DTWs and LLPs, first to farmers' co-operatives, and later to individual farmers, many of whom became

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