INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI

IFPRI Discussion Paper 01488

December 2015

Farm Household Typologies and Mechanization Patterns in Nepal Terai

Descriptive Analysis of the Nepal Living Standards Survey

Hiroyuki Takeshima

Rajendra Prasad Adhikari

Mahendra Nath Poudel

Anjani Kumar

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), established in 1975, provides evidence-based policy solutions to sustainably end hunger and malnutrition and reduce poverty. The Institute conducts research, communicates results, optimizes partnerships, and builds capacity to ensure sustainable food production, promote healthy food systems, improve markets and trade, transform agriculture, build resilience, and strengthen institutions and governance. Gender is considered in all of the Institute's work. IFPRI collaborates with partners around the world, including development implementers, public institutions, the private sector, and farmers' organizations, to ensure that local, national, regional, and global food policies are based on evidence. IFPRI is a member of the CGIAR Consortium.

AUTHORS

Hiroyuki Takeshima (h.takeshima@cgiar.org) is a research fellow in the Development Strategy and Governance Division of the International Food Policy Research Institute (IFPRI), Washington, DC.

Rajendra Prasad Adhikari is joint secretary in the Policy and International Cooperation and Coordination Division of the Nepal Ministry of Agriculture Development, Katmadu.

Mahendra Nath Poudel is a senior agricultural economist in the Policy and International Cooperation and Coordination Division of the Nepal, Ministry of Agriculture Development, Katmadu.

Anjani Kumar is a research fellow in the South Asia Office of IFPRI, New Delhi.

Contents

Tables

Figures

ACKNOWLEDGMENTS

We thank the United States Agency for International Development for providing funding for this study through the Policy Reform Initiative Project. We are also grateful for the constructive comments of the participants of the Stakeholder Consultation Meeting held in Kathmandu in September 2015. We also thank Madhab Karkee, and Deva Bhakta Shakya for overall guidance and facilitation. Views expressed in this paper are those of the authors, and are not necessarily representative of or endorsed by the government of Nepal, the International Food Policy Research Institute, or USAID. We are responsible for all remaining errors.

ABSTRACT

Although Nepal formulated an agricultural mechanization promotion policy in 2014, there is still much to learn about tailoring mechanization policies to different types of farm households. The Terai belt in Nepal has seen steady growth in tractor use in the past 20 years, but heterogeneity exists among farm households. In this study, we use Nepal Living Standards Survey data to analyze such heterogeneity from a farm typology perspective. We characterize farm households based on use of external agricultural inputs, including tractors. Growth of tractor use in the Terai is associated with input use intensification per cultivated area, rather than significant expansion of cultivated area. Tractor use in the Terai appears to have grown as part of such land-saving intensification, although larger farm owners do hire in more tractors. We find that differences in household income portfolios are not straightforward between tractor renters and nonrenters, without clear differences in specialization of economic activities as well as farming systems. Tractor renters consist of various types, including the power-intensive mechanizer, intensive labor hirer, and fertilizer-based intensifier. Such heterogeneity recommends the use of tailored mechanization policy options.

Keywords: farm household typology, mechanization, modified cluster analysis, Nepal

1. INTRODUCTION

Nepal's Terai belt has seen rapid growth in tractor use in the past 20 years, without substantial farm size expansion. The Nepalese government's recently formulated Agricultural Mechanization Promotion Policy 2014 aims in part to reduce food production costs through improving mechanization efficiency. Although the Terai is relatively homogeneous within Nepal's diverse production environments, significant heterogeneity exists among farm households across regions. It is important to assess how mechanization policies can be tailored to specific types of farmers.

The growth in mechanization in the Terai has occurred alongside changes in other sectors of the economy. Whereas the agricultural sector still accounts for a large share of the economy (around one-third of national gross domestic product), the manufacturing and service industries have started growing, and remittances have become an important source of income for many households. In the meantime, smallholder households still dominate the agricultural sector. It is important to understand how tractor adoption in the Terai has taken place alongside these other economic changes. Although agricultural mechanization patterns in Nepal have been studied (Justice and Biggs 2013; Takeshima 2015a), relatively less is known about the types of households that have emerged as owners or users of tractors, with respect to household characteristics, farming systems, and household economic activities.

We use three rounds of the Nepal Living Standards Survey (NLSS) to study such heterogeneity from a farm typology perspective. In particular, the paper provides insight into (1) the current level of mechanization, particularly tractor use; (2) how endowments of land and labor have changed in different agroecological belts in Nepal; (3) what types of households are found in the Terai in terms of economic activities and revenue sources; (4) what type of farm households own or use tractors; and (5) how mechanization-based farm input use intensification compares with other types of input use intensification.

Nepal's Central Bureau of Statistics conducted the NLSS in 1995, 2003, and 2010. A multi-topic survey developed following the World Bank's Living Standards Measurement Survey methodology, the NLSS covers consumption, income, employment, access to facilities, education, and health; the survey also includes agricultural modules covering the production of crops and livestock, the use of inputs, and ownership of agricultural assets like tractors. Each round of data was collected based on multistage stratified random sampling methods, involving enumeration areas that were randomly selected from six strata across Nepal and that consist of urban and rural areas in each of three agroecological belts (Terai, Hills, and Mountains).[1] In NLSS 1995, the enumeration areas consisted of 275 wards, from which 3,388 households were sampled. In NLSS 2003, 4,008 cross-section samples were randomly selected from 800 enumeration areas, and 1,232 panel samples were randomly selected from NLSS 1995. In NLSS 2010, 5,988 cross-section samples were randomly selected from 500 enumeration areas redefined from the 800 enumeration areas in NLSS 2003, and 1,032 panel samples were randomly selected from NLSS 2003. Within each enumeration area, households were randomly selected for the interview (Nepal, Central Bureau of Statistics 1996, 2004, 2011a). To retain the representativeness, we use only cross-sectional samples. Most of our discussion focuses on the farm households defined specifically in this paper, as described in a later section.

The paper is largely based on the descriptive statistics, combined with some cluster analysis, rather than rigorously investigating causal mechanisms. Our objective is to obtain a broad picture of the key dimensions of farm household characteristics and farming systems that are associated with mechanization growth in the Terai. Having identified such key dimensions, future studies can investigate more deeply the role of mechanization growth in agricultural transformation patterns in Nepal.

[1] For NLSS 1995, only the Hills region was further stratified into urban and rural.

2. HOUSEHOLD CHARACTERISTICS IN NEPAL—FROM THE NEPAL LIVING STANDARDS SURVEY [2]

We first define the *farm households* classified in this paper. Based on the NLSS, approximately 80 to 93 percent of households in Nepal, depending on the year, had at least one member working in the agricultural sector (Table 2.1). For simplicity, this paper treats all such households as farm households. In the Terai, 94, 90, and 81 percent of households were farm households in 1995, 2003, and 2010, respectively. Some were landless farm households whose members worked for farms owned by other households, but they themselves were not involved in farmland transactions. Farm households that also transact land (either through owning, sharecropping, renting in, or mortgaging in) are called *landed farm households* in this paper. Landed farm households are those that cultivate plots of any type under their own management—so they include households cultivating their own or rented land but exclude those households that only supply agricultural labor to other households. They constituted 76, 73, and 72 percent of households in the Terai in 1995, 2003, and 2010, respectively, or 81, 81, and 89 percent of farm households. These may not be the official classifications in Nepal but are convenient for the purposes of this paper.

Table 2.1 Percentage of households with at least one member working in agriculture

Ecological belt/ Development region	1995	2003	2010	1995	2003	2010	1995	2003	2010
	Percentage of households with at least one member working			Percentage of farm households (households with at least one member working in agriculture)					
				Including landless			With access to farm (own, sharecropping in, renting in, and so forth)		
Total	99	99	96	93	88	80	83	78	76
Terai	99	100	96	94	90	81	76	73	72
Eastern	99	100	96	91	90	77	62	66	67
Central	99	100	96	95	93	84	76	71	72
Western	99	99	94	98	88	77	88	82	74
Midwestern	100	99	95	97	82	82	84	76	78
Far Western	100	100	99	96	92	91	94	89	86
Hills	99	99	95	90	83	78	88	80	76
Mountains	98	100	98	98	99	92	97	96	91

Source: Authors' calculations based on NLSS (Nepal, CBS 1996, 2004, 2011a).

Mechanization Levels in Nepal—with the Focus on Tractors

An increasing share of Nepalese farm households, particularly in the Terai, use tractors either through ownership or renting. Table 2.2 summarizes the shares of farm households using tractors, differentiated by ecological belt (Terai, Hills, and Mountains) and region as well as districts in the Terai. In Nepal as a whole, the share of farm households using tractors increased from 5 percent in 1995 to 16 percent in 2003 and 23 percent in 2010, while the share of tractor owners remained at 1 percent or less. In the Hills and the Mountains growth has been much slower. The highest shares are found in the Central zone of the Hills (20 percent). On the contrary, in the Terai, the share increased from 8 percent in 1995 to 29 percent in 2003 and 46 percent in 2010, with tractor owners increasing as well to 2 percent of farm households in 2010. Within the Terai, tractor use grew first in the Central and Western regions, but use in the Far Western, Eastern, and Midwestern regions has started catching up. In some districts—like Bara, Chitwan, Nawalparasi, Parsa, and Rupandehi—approximately half or more of farm households used tractors in

[2] To approximate the variations in price levels across time and space, all monetary values are deflated by the average of district median prices of major cereals (rice and wheat) calculated from the NLSS. We use the average of those crops, instead of a single crop, even though prices vary between those crops. We do this because households are likely to substitute between rice and wheat depending on their relative price, and using the average price of both crops may better approximate the costs of basic food.

2003, and three out of four farm households did in 2010. The share has also increased to at least 20 to 50 percent in other districts, except Dang. Altogether, albeit with interdistrict variations, tractor use has generally grown consistently in the Terai.

Table 2.2 Percentage of farmers using tractors by ecological belt (including landless households)

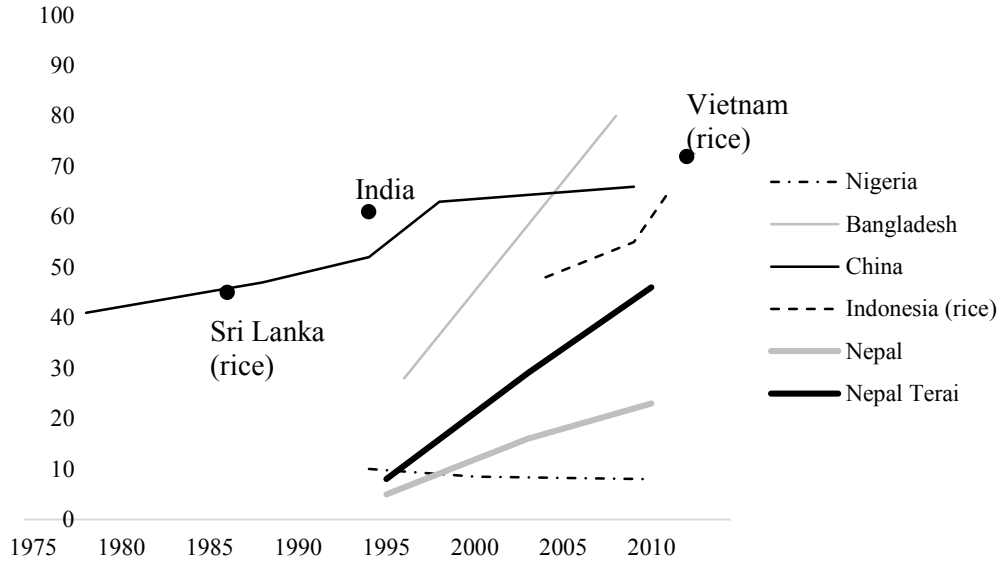
Ecological belt/ Development region/ District	1995	2003	2010/11
Total	**5 (0.8)**	**16 (0.4)**	**23 (1)**
Terai	**8 (0.9)**	**29 (1)**	**46 (2)**
Eastern	**2 (1)**	**13 (1)**	**33 (2)**
Jhapa	1 ± 3 (0 ± 0)	8 ± 5 (0 ± 0)	41 ± 10 (1 ± 1)
Morang	3 ± 4 (1 ± 3)	10 ± 6 (1 ± 2)	36 ± 9 (1 ± 1)
Saptari	0	21 ± 9 (0 ± 0)	26 ± 9 (1 ± 2)
Siraha	0	15 ± 9 (2 ± 3)	40 ± 10 (1 ± 1)
Sunsari	4 ± 5 (1 ± 2)	12 ± 7 (1 ± 3)	21 ± 9 (5 ± 5)
Central	**11 (1)**	**39 (1)**	**56 (2)**
Bara	16 ± 10 (0 ± 0)	67 ± 12 (3 ± 5)	83 ± 11 (2 ± 3)
Chitawan	18 ± 12 (6 ± 7)	58 ± 10 (0 ± 0)	87 ± 8 (1 ± 3)
Dhanusa	5 ± 5 (0 ± 0)	25 ± 9 (0 ± 0)	46 ± 11 (3 ± 3)
Mahottari	9 ± 8 (0 ± 0)	13 ± 8 (1 ± 3)	34 ± 11 (1 ± 3)
Parsa	7 ± 8 (0 ± 0)	55 ± 14 (0 ± 0)	74 ± 11 (1 ± 2)
Rautahat	16 ± 10 (0 ± 0)	34 ± 13 (0 ± 0)	36 ± 11 (3 ± 4)
Sarlahi	8 ± 7 (0 ± 0)	30 ± 10 (0 ± 0)	46 ± 12 (1 ± 3)
Western	**15 (2)**	**56 (1)**	**72 (3)**
Kapilbastu	8 ± 8 (2 ± 4)	22 ± 11 (0 ± 0)	65 ± 10 (4 ± 4)
Nawalparasi	17 ± 10 (1 ± 4)	69 ± 11 (1 ± 3)	76 ± 8 (3 ± 3)
Rupandehi	18 ± 9 (1 ± 3)	71 ± 12 (2 ± 3)	74 ± 9 (3 ± 3)
Midwestern	**4 (1)**	**4 (0)**	**24 (0)**
Banke	4 ± 8 (0 ± 0)	4 ± 7 (0 ± 0)	27 ± 11 (2 ± 3)
Bardiya	0	8 ± 8 (0 ± 0)	37 ± 10 (0)
Dang	8 ± 8 (2 ± 5)	0	10 ± 6 (0)
Far Western	**5 (0)**	**26 (3)**	**34 (2)**
Kailali	7 ± 7 (0 ± 0)	28 ± 11 (2 ± 3)	33 ± 9 (1 ± 2)
Kanchanpur	3 ± 7 (0 ± 0)	24 ± 13 (4 ± 5)	36 ± 10 (2 ± 3)
Hills	**2.7 (0.7)**	**5 (0.3)**	**8 (0.3)**
Eastern		**0 ± 1 (0 ± 0)**	**2 ± 2 (0 ± 0)**
Central		**9 ± 3 (0 ± 1)**	**20 ± 3 (1 ± 1)**
Western		**4 ± 2 (0 ± 0)**	**5 ± 2 (0 ± 0)**
Midwestern		**0 ± 1 (0 ± 0)**	**1 ± 1 (0 ± 0)**
Far Western		**0 ± 0 (0 ± 0)**	**0 ± 0 (0 ± 0)**
Mountains	**0.7 (0.7)**	**1 (0)**	**2 (0)**

Source: Authors' calculations based on NLSS (Nepal, CBS 1996, 2004, 2011a).

Note: Figures after ± represent 95% margin of error based on symmetric assumptions and adjusted for village development committee cluster. Numbers in parentheses equal percentage who use their own tractors.

The level of mechanization in Nepal, measured as the share of cultivated area plowed by tractor, still lags behind other countries in Asia (Figure 2.1). However, in the Terai it is growing twice as fast as in the whole country and is rapidly catching up to other countries.

Figure 2.1 Percentage of cultivated area plowed by tractor



Source: Various. Bangladesh in 1996: Ahmed (2001) cited by Kienzle et al. (2013 p72); Bangladesh in 2008: Roy & Singh (2008). China, Indonesia: CSAM (2014): India: Ugwuishiwu & Onluwal (2009 Table 1). Indonesia: Sri Lanka: International Rice Research Institute (IRRI). (1986). Nigeria in 1994: Ugwuishiwu & Onluwal (2009 Table 1): Nigeria in 2000: Azogu (2009): Nigeria in 2010: Takeshima et al. (2013).

Note: Figures for Nepal are based on share of households using tractors estimated from NLSS. Figure for Nigeria in 2000 is for northern Nigeria.

The growth of tractor use in the Terai has generally been gender neutral. Although the share of male-headed households using tractors has been consistently higher than the share of female-headed households3 over time, the gap has not widened (Table 2.3). Even among female-headed households, 40 percent were already using tractors in 2010 in the Terai. The fast growth of female-headed households using tractors in the Terai is in contrast to the pattern in the Hills.

Table 2.3 Percentage of agricultural households in the Terai (including landless households) owning or using tractors, by gender of household head

Ecological belt/Gender	Using tractor		
	1995	2003	2010
Terai			
Male	9* ± 2	30* ± 3	47* ± 3
Female	1 ± 2	24 ± 6	40 ± 5
Hills			
Male	2 ± 1	4 ± 1	8* ± 1
Female	2 ± 2	3 ± 2	5 ± 2

Source: Authors based on NLSS (Nepal, CBS 1996, 2004, 2011a).

Note: Asterisk indicates a significant difference across gender at the 10% level. Figures after ± represent 95% margin of error based on symmetric assumptions and adjusted for village development committee cluster.

[3] Female-headed households are households whose reported heads are female in the NLSS.

The growth of tractor use is driven by tractor rentals (hiring services) rather than tractor ownership. Table 2.4 summarizes the estimated area tractored by owned and rented/hired tractors. Figures are estimated assuming that those owning or renting tractors use tractors on all of their plots. When calculated this way, tractored areas in the Terai grew by 1,331,000 hectares from 499,000 hectares to 1,830,000 hectares between 1995 and 2010. The growth of tractored areas by rented tractors during this period was 1,130,000 hectares, which accounts for more than 80 percent of the total growth of tractored area.

Table 2.4 Estimated area cultivated by owned tractors and hired tractors (in 1,000 hectares)

Ecological belt	Source	1995	2003	2010
Terai	Owned tractors	59	108	260
	Rented tractors	440	954	1,570
	Total	499	1,062	1,830
Hills and Mountains	Owned tractors	14	17	4
	Rented tractors	28	40	113
	Total	42	57	117
Nepal	Owned tractors	73	125	264
	Rented tractors	468	994	1,683
	Total	541	1,119	1,947

Source: Authors' estimations based on NLSS (Nepal, CBS 1996, 2004, 2011a).
Note: Figures are estimated assuming that those renting tractors use tractors on all of their plots, since the NLSS does not report the area on which tractors were used. Payment for tractor rental per household varies, but in 2010 Terai households paid an amount worth 200 kilograms of cereals on average and 120 at the median (Table 2.5). Figures in the Hills and the Mountains are slightly lower—an amount worth around 50 to 150 kilograms of cereals.

Table 2.5 Average and median payments for tractor services per household, among tractor renters, measured in kilograms of cereals

Ecological belt	1995	2003	2010
Terai	140 (97)	181 (117)	207 (121)
Hills	107 (86)	107 (65)	145 (92)
Mountains			64 (41)
Total	135 (90)	174 (117)	198 (121)

Source: Authors based on NLSS (Nepal, CBS 1996, 2004, 2011a).
Note: Figures in parentheses are medians.

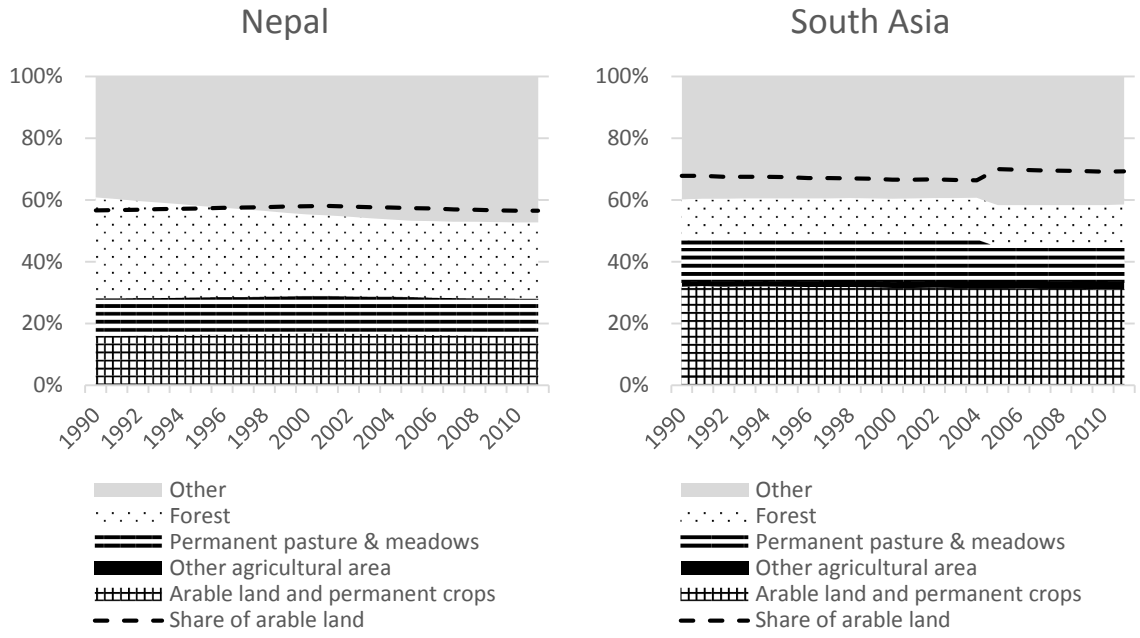
Factor Endowments

The demand for labor-intensive farming and agricultural mechanization is largely affected by endowments of land and labor, among others. Here we highlight key changing trends in those factor endowments in Nepal.

Land and Tenure

In Nepal, overall land endowments have not changed substantially over the past few decades. Although land fragmentation has continued, farmland has not expanded in Nepal in the past 20 years (Figure 2.2). Neither the substantial clearing of forests nor the conversion of permanent pasture and meadows has taken place since the 1990s. While these figures are at the country level, the pattern is expected to be similar in the Terai. In other words, the aforementioned growth in tractor use in the Terai has not accompanied significant expansion of aggregate farmland area.

Figure 2.2 Land use in Nepal and South Asia



Source: FAO (2014).
Note: "Other agricultural area" may include fallow land, and any other type of agricultural land that is not categorized under either permanent pasture and meadows or arable land and permanent crops.

In the Terai, the de facto land tenure system has been relatively fixed as well over the past two decades (Table 2.6). Between 1995 and 2010, approximately 90 percent of landed farm households owned their farm plots, 25 to 30 percent had plots that were sharecropped in, and 4 to 8 percent had rented plots. The total exceeds 100 percent because some landed farm households put their lands into multiple tenure types of plots. The pattern has not changed substantially, except for a slight increase in the share of rented-in plots and a decrease in the share of sharecropped-in plots. Land tenure patterns are broadly similar between tractor users and nonusers.

Table 2.6 Percentage of landed farm households by type of land access and tractor use, the Terai

Category	1995					2003					2010/11				
	All	Tractor owner	Tractor renter	Draft animal	Non-user	All	Tractor owner	Tractor renter	Draft animal	Non-user	All	Tractor owner	Tractor renter	Draft animal	Non-user
Own farmland	92	100	96	86	93	88	100	90	87	83	92	100	93	91	83
Sharecropping in	29	35	31	26	29	30	10	28	35	16	25	14	24	29	13
Renting in	4	0	4	5	4	8	0	11	7	2	7	7	10	6	3
Mortgage in	2	0	3	3	2	4	0	4	4	2	3	0	3	3	3
Other	3	0	1	4	4	3	10	2	3	7	3	4	3	2	6

Source: Authors' calculations based on NLSS (Nepal, CBS 1996, 2004, 2011a).

Land access differs more clearly across mechanization types in terms of land size. Table 2.7 summarizes farmland endowments per working-age household members, differentiated by tractor use status, which roughly approximates the land-to-labor ratio. This is based on land endowments, not cultivated area. Differences between tractor owners and others are clear; a greater own-land-to-labor ratio is associated with tractor ownership. In 2010, tractor owners owned, on average, 1.29 hectares per working-age household member, while other farm households had less than 0.3 hectare per working-age household member. These differences have widened over time. Between tractor renters and nonusers, differences are less clear. In one way, tractor renters seem to be slightly more endowed with own land than labor, compared to nonusers (about 30 to 40 percent higher land endowments in both 1995 and 2010). However, it is unclear to what extent tractor use is attributed to these differences in endowment.

Interestingly, the land-to-labor ratio measured in this way decreased up to 2003 from 0.28 (hectare per working-age household member) to 0.24, but since then started rising slightly to 0.26 in 2010. That slight increase is more pronounced among tractor owners, as well as households using only rented tractors. This is likely to be because of the growing outmigration from rural areas. While this pattern is subtle, it does show that land fragmentation in the Terai has stopped, potentially reducing the bottleneck against increased mechanization.

Table 2.7 Annual cultivated area (hectares) per working-age household member, the Terai

Category	All farm households			Tractor owners				Tractor users (rent only)			Draft animal only			Nonusers		
Year[a]	95	03	10	95	03	10H	10L	95	03	10	95	03	10	95	03	10
Total	.28	.24	.26	.54	.87	1.11	2.08	.49	.31	.34	.23	.28	.22	.26	.03	.04
Own farmland	.22	.17	.21	.49	.81	1.03	2.03	.40	.23	.26	.19	.19	.16	.21	.03	.03
Sharecropping in	.04	.05	.04	.05	.05	.06	.03	.07	.05	.05	.03	.07	.04	.04	.00	.01
Renting in	.01	.01	.01	.00	.00	.01	.01	.02	.02	.02	.01	.01	.01	.01	.00	.00
Mortgage in	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Other	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00
Median																
Total	.17	.14	.15	.42	.67	.59	.68	.41	.22	.22	.11	.18	.14	.17	.00	.00
Own farmland	.11	.08	.09	.33	.62	.59	.59	.27	.13	.15	.07	.09	.08	.10	.00	.00
Mean land owned per capita (hectares/capita)	.17	.13	.15	.29	.50	.57	1.16	.22	.13	.16	.12	.14	.11	.17	.09	.11

Source: Authors.

Notes: [a] "10H" and "10L" under "tractor owners" are owners of high-price tractors and low-price tractors in 2010, respectively, where high-price tractors are those that at the time of purchase were worth more than 20 metric tons of cereals.

Table 2.8 summarizes the area (in hectares) of land cultivated per household, differentiated by mechanization status. Figures are not per working household member, unlike in Table 2.7, as actual labor use is endogenous (it depends on the area cultivated). These figures combine all farmland cultivated in the dry season and the rainy season, some lands of which were owned, sharecropped in, or rented in or mortgaged in. If the same plot was cultivated in both the dry season and the rainy season, we count it twice. Figures in parentheses are the mean area (hectares) of land owned.

Table 2.8 Mean area (hectares) cultivated by farm households, by tractor use status

Ecological belt/ Development region	1995				2003				2010			
	Owner	Tractor renter	Draft animal	Non-user	Owner	Tractor renter	Draft animal	Non-user	Owner	Tractor renter	Draft animal	Non-user
Terai	**5.0**	**3.7**	**1.2**	**1.8**	**7.4**	**1.9**	**1.7**	**0.14**	**7.3**	**1.7**	**1.0**	**0.12**
Lowland	2.4	3.0	1.0	1.5	6.7	1.7	1.5	0.10	6.6	1.5	0.9	0.08
	(2.8)	**(1.8)**	**(0.6)**	**(0.9)**	**(4.3)**	**(0.8)**	**(0.8)**	**(0.1)**	**(3.8)**	**(0.8)**	**(0.5)**	**(0.2)**
Eastern	6.9	5.0	1.4	2.7	4.5	3.0	2.2	0.3	5.6	2.3	1.1	0.2
	(6.3)	(1.9)	(0.7)	(1.4)	(1.9)	(1.4)	(0.9)	(0.5)	(3.1)	(1.0)	(0.4)	(0.4)
Central	4.3	2.6	1.0	1.7	3.9	1.6	1.2	0.3	10.7	1.4	1.2	0.2
	(2.1)	(1.4)	(0.4)	(0.8)	(1.7)	(0.7)	(0.6)	(0.2)	(5.6)	(0.7)	(0.5)	(0.2)
Western	3.7	4.5	1.4	2.1	15.8	1.6	1.8	0.5	4.6	1.4	1.4	0.3
	(1.4)	(1.9)	(0.8)	(1.1)	(11.9)	(0.7)	(0.7)	(0.6)	(2.5)	(0.7)	(0.6)	(0.4)
Midwestern	8.3	8.0	1.7	2.4		4.9	2.2	0.2	2.2	1.8	1.2	0.3
	(4.1)	(4.1)	(1.0)	(0.9)		(0.7)	(1.1)	(0.3)	(1.1)	(0.8)	(0.5)	(0.5)
Far Western		6.0	0.6	3.1	8.0	3.0	2.0	0.3	7.2	1.8	1.0	0.2
		(2.8)	(0.8)	(1.6)	(4.0)	(1.3)	(0.8)	(0.2)	(2.9)	(0.9)	(0.5)	(0.2)
Hills	1.1	1.1	1.2	1.5	5.1	0.7	1.3	0.3	0.9	0.7	1.1	0.3
	(0.7)	(0.6)	(0.6)	(0.8)	(2.6)	(0.3)	(0.7)	(0.3)	(0.4)	(0.4)	(0.6)	(0.3)
Mountains	1.4		2.3	2.1			1.6	0.5		0.7	1.3	0.5
	(0.7)		(1.1)	(1.1)			(0.9)	(0.5)		(0.4)	(0.7)	(0.4)

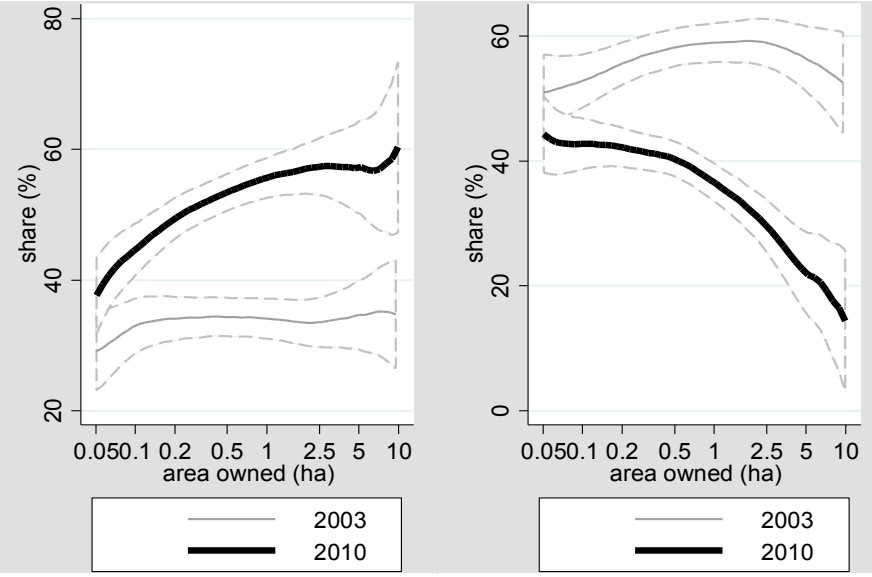
Source: Authors' calculations based on NLSS (Nepal, CBS 1996, 2004, 2011a).
Note: Figures in parentheses represent mean area owned.

In all regions, tractor owners both owned and cultivated much larger areas than nonowners. Among nonowners of tractors, both owned areas and cultivated areas have declined over time. In the Terai, households renting tractors consistently owned and cultivated larger areas than nonusers. Patterns are, however, somewhat different in the Hills and the Mountains, suggesting different tractorization mechanisms at work in the Terai and in other regions.

Since 2003, households using neither tractors nor draft animals have owned consistently small land areas, 0.1 to 0.2 hectare on average. Moreover, such households have typically cultivated less land, 0.12 to 0.14 hectare on average, one-third of which is upland. In 1995 and 2003, approximately 8 and 10 percent, respectively, of such households rented out their land for revenue.

The widening difference in land endowment between tractor renters and draft-animal-only users is not due to the difference in land transactions (that is, similar shares of each type of household sold or purchased land during one year prior to the 2010 survey). It is rather because households with larger land endowments disproportionately switched from draft animals to tractors between 2003 and 2010. Figure 2.3 illustrates the relationship between the share of farm households renting in tractors and hectares of farmland owned (left panel) and between the share of households using draft animals only and hectares of farmland owned (right panel), estimated through local polynomial regression. Broken lines represent the boundaries of the pertinent 90 percent confidence intervals. Figure 2.3 indicates the statistically significant differential rates of growth in the use of rented tractors and reduction in the use of animal traction, across different sizes of farmland owned.

Figure 2.3 Share of Terai households renting tractors or using only draft animals, by land ownership (left = tractor renters; right = draft animal only)



Source: Authors' estimation using local polynomial regression.

Labor

The population of the Terai has grown at a faster pace than that of the Hills and the Mountains in the past two decades (Table 2.9), generally growing 0.7 percentage point faster annually than in the Hills and 1.1 to 1.2 percentage points faster annually than in the Mountains. This may reflect the growing migration from the Mountains or Hills to the Terai. Migration is common within Nepal, to the extent that it can sometimes saturate the receiving community (Maystadt, Mueller, and Sebastian 2014). Therefore, labor endowments have generally grown faster in the Terai than in the Hills or the Mountains, even though the pace of mechanization has also been faster in the Terai.

Table 2.9 Population growth by ecological belt

Year	Mountains	Hills	Terai	Total
1971 (000s)	1,139	6,071	4,346	11,556
1981(000s)	1,303	7,163	6,557	15,023
1991(000s)	1,443	8,420	8,628	18,491
1995 estimated (000s)	1,536	9,109	9,581	20,226
2001(000s)	1,688	10,251	11,212	23,151
2010 estimated (000s)	1,772	11,274	13,092	26,138
2011(000s)	1,782	11,394	13,319	26,495
% / year (1991–2011)	1.1	1.5	2.2	1.8
% / year (2001–2011)	0.5	1.0	1.7	1.4

Source: Nepal CBS (2001, 2011b).

Nevertheless, real farm wages have also risen over time in all of the Terai, together with the Hills and the Mountains (Table 2.10). In the Terai, real wages increased by about 50 percent between 1995 and 2010, with relatively small variations across regions. Although real wages were relatively lower in the Central region and higher in the Far Western zone in 1995 and 2003, those variations had almost disappeared in 2010 (though intraregional variations may still exist). Generally rising real farm wages are consistent with growing mechanization. Interestingly, although wages have risen at a similar pace in the Hills and the Mountains, tractor adoption is much slower in those regions, as we saw earlier. The increase in real wages therefore partly explains the growth in mechanization in the Terai, but the effects of wages seem to differ between the Terai and other zones.

Table 2.10 Real farm wages (village district median) (ratio of daily wage to 1 kilogram of rice and wheat price)

Ecological belt/ Development regions	1995					2003					2010/11				
	All	Tractor owners	Tractor renters	Draft animal users	Non-mechanized	All	Tractor owners	Tractor renters	Draft animal users	Non-mechanized	All	Tractor owners	Tractor renters	Draft anima users	Non-mechanized
Terai	**8**	**8**	**8**	**8**	**8**	**10**	**10**	**10**	**10**	**10**	**12**	**12**	**12**	**12**	**12**
Eastern	8	8	8	8	8	10	10	10	10	10	12	12	12	12	12
Central	7	7	8	7	6	10	10	10	10	10	12	12	12	12	12
Western	8	8	8	8	8	10	11	11	11	10	12	12	12	12	12
Midwestern	8	8	8	8	8	10		11	10	10	12	12	12	12	12
Far Western	9		8		10	10	12	12	11	10	12	12	12	12	12
Hills	7	7	8	7	7	9	9	11	9	9	11	11	11	11	11
Mountains	7	6		7	7	10			10	10	12		12	12	12

Source: Authors' calculations.

Note: Wages are averages of daily male wages for plowing, planting, weeding, and harvesting.

Farm wages might have been partly driven up by rising human capital, measured in terms of education. Human capital grew in Nepal between 1995 and 2010 (Table 2.11). Average years of total schooling among the population 15 years old or above increased almost 60 percent from 2.65 to 4.23 during this period. Such an improvement occurred sometimes despite disruptions caused by civil conflicts (Pivovarova and Swee 2015). This is mostly a reflection of increasing enrollment as well as completion of primary school education and secondary school education. This is likely to be so particularly among young people.

Table 2.11 Changes in level of human capital among people 15 years old or older in Nepal

Year	No schooling (%)	Primary school		Secondary school		Tertiary school		Average years of total schooling	
		Enrolled	Completed	Enrolled	Completed	Enrolled	Completed	+ 15	+ 25
1950	99	0	0					0.11	0.05
1980	85	7	3					0.99	0.63
1995	62	15	7	19	6	4	2	2.65	2.24
2000	53	23	11	21	8	3	2	2.97	2.37
2005	45	27	15	25	10	3	2	3.55	2.80
2010	36	31	19	30	13	3	2	4.23	3.31

Source: Authors' compilation from Barro and Lee (2013).

Since Barro and Lee (2013) provide only national averages, we also calculate similar figures of average education levels across regions using the NLSS. Table 2.12 summarizes the estimated average years of completed education for the population 15 years or older. Using classifications in the NLSS, the following assumptions are made: classes 1 through 10 = 1 through 10 years; School Leaving Certificate = 10; intermediate level / plus two levels, professional degree = 12; bachelor's/professional degree = 16; master's or higher = 18. Average figures for the nation are on a similar order to those of Barro and Lee shown in Table 2.11.

Table 2.12 Estimated average years of total schooling by region (15 years old or older)

Ecological belt/ Development region	1995	2003	2010
Terai	2.3	3.3	4.3
Eastern	2.8	3.8	4.8
Central	2.0	2.7	3.6
Western	2.3	3.9	4.5
Midwestern	2.2	3.0	4.6
Far Western	1.9	3.2	5.1
Hills	2.9	4.2	5.3
Mountains	1.5	2.7	3.8
All	2.5	3.7	4.7

Source: NLSS (Nepal, CBS 1996, 2004, 2011).

Education levels have risen consistently across all regions and ecological belts. In the Terai, we see an increase from 2.3 years in 1995 to 4.3 years in 2010. Levels have risen in the Hills and the Mountains as well. Rising human capital levels are positively correlated with the rising real farm wages in Table 2.10. Some variations, however, exist across regions. The Terai Central region is at 3.6 years in 2010, lagging behind other regions in the Terai, while the Terai Far Western region has seen the fastest increase to 5.1 years. This is somewhat in contrast to the fact that mechanization has grown faster in the Terai Central compared with the Terai Far Western (Table 2.2), and real wages do not vary across regions in the Terai (Table 2.10).

Overall, rising human capital measured as years of education seems to explain, in part, rising real farm wages and growing mechanization in the Terai. But some variation in these patterns exists across regions and ecological belts.

There is some association between tractor use and the aging of agricultural workers. In 2010, the average age of workers weighted by the days of work engaged in the Terai was 38 and 35 for wage work in agriculture and nonagriculture (Table 2.13), respectively, indicating that the average age of wage workers in the agricultural sector was approximately three years higher than that in the nonagricultural sector. In addition, the average age of self-employed agricultural workers is slightly higher in tractor-using farm households than non–tractor users in the Terai (40 compared with 38) and the Hills (41 compared with 37), while the age of wage workers in the nonagricultural sector was 34 for tractor-using households compared with 38 for non–tractor users in the Hills.

Table 2.13 Tractor use and aging of agricultural workers among agricultural households (weighted average by number of days worked), 2010

Ecological belt/Subcategory	Wage work in agriculture	Wage work in nonagriculture	Self-employed agriculture	Self-employed nonagriculture
Terai	38**	35	39	39
Tractor user / nonuser	39 / 38	35 / 35	40 / 38**	38 / 39
Hills	37	37	37**	41
Tractor user / nonuser	40 / 37	34 / 38*	41 / 37**	41 / 40
Mountains	37	37	36**	41
Tractor user / nonuser	38 / 37		37 / 36	31 / 41

Source: Authors. Asterisks indicate statistically significant differences between tractor user and nonusers:
Note: ** 1% * 5%. Figures are calculated as the average age of workers, weighted by the number of days worked for each type of work.

Draft Animals—Potentially Substituted for by Tractors

Draft animals have been widely used in Asia as intermediate tools for agricultural mechanization, and they have gradually been substituted for by tractors. In Nepal, based on the NLSS, the major draft animals owned are bullock and buffalo (Table 2.14). The use of horses, donkeys, or mules appears uncommon.

Table 2.14 Percentage of draft animals owned by draft animal owners

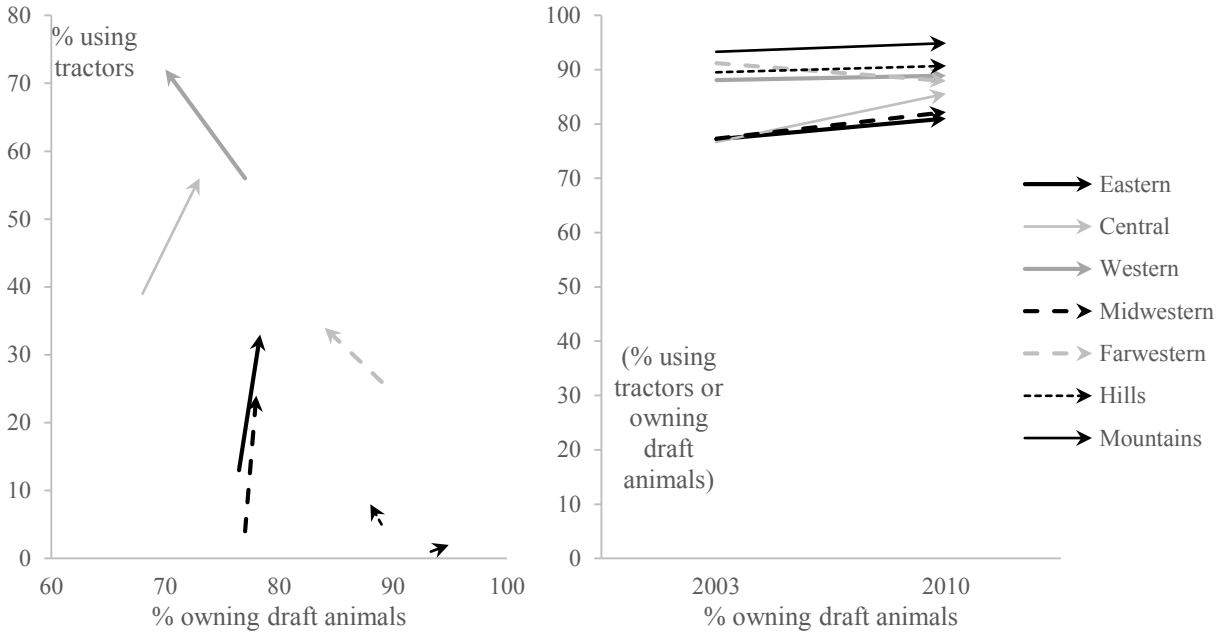
Type of draft animal	Terai		Hills		Mountains	
	2003	2010	2003	2010	2003	2010
Bullock/cow	81	75	78	78	85	90
Buffalo	50	52	70	67	58	48
Horse/donkey/mule	1	2	1	1	4	1

Source: Authors.

Figure 2.4 illustrates patterns of draft animal holdings and tractor use in each zone and the regions within the Terai. Substitutions between draft animals and tractors are modestly observed. Between 2003 and 2010, shares of draft animals decreased more in zones/regions with higher tractor use shares, such as the Terai Western and Terai Far Western regions. Note that these figures do not condition variations in the costs of animal husbandry and feedstock, and should not be interpreted with any causal implications.

Importantly, however, the share of nonmechanized farm households that are using neither draft animals nor tractors remained relatively flat between 2003 and 2010 at about 5 to 25 percent of farm households. Some of those are landless farm households, but the majority are landed farm households. Substitutions of labor to draft animals or tractors among these nonmechanized households seem not to have happened substantially between 2003 and 2010. Nonmechanized farm households may therefore be structurally different from other farm households.

Figure 2.4 Shares of draft animal owners and tractor users in each region/zone



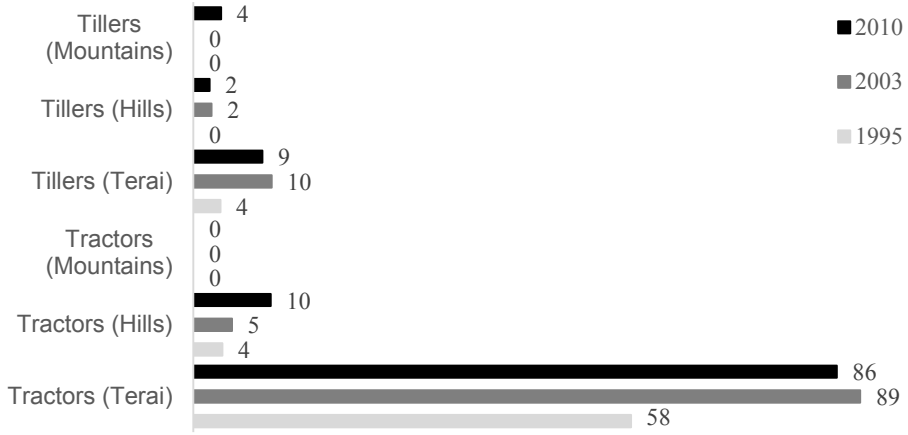
Source: Authors' calculations based on NLSS (Nepal, CBS year).
Note: Draft animals include bullock/cow, buffalo, horse/donkey/mule (bullock/cow, horse/donkey/mule cannot be separated).

Supply of Mechanization Service

In countries where medium to larger four-wheel tractors dominate, farm mechanization is typically provided by a small number of tractor owners through custom hiring services. This has been observed in West African countries such as Nigeria and Ghana (Takeshima, Nin Pratt, and Diao 2013; Takeshima et al. 2015; Houssou, Diao, and Kolavalli 2014). Nepal currently is in a similar situation. The number of households using rented tractor services is almost 20 times the number of tractor-owner households (Table 2.2), suggesting that one tractor owner provides hiring services to roughly 20 farm households.

The share households with access to rented tractors or power tillers varies considerably across agroecological belts (Figure 2.5) and is consistent with the share of households adopting tractors in Table 2.2. Tractors are widely and increasingly available in the Terai (60 percent of households had access in 1995, and close to 90 percent in 2003 and 2010). On the other hand, only 10 percent of households had access in 2010 in the Hills. The availability of tillers has generally been low in all agroecological belts, with only 10 percent of households having access in the Terai, and even lower shares in the Hills and the Mountains. This is consistent with the limited availability of tractor rental services experienced in developing countries like Nigeria (Takeshima 2015b).

Figure 2.5 Percentage shares of farm households with access to rented tractors or power tillers



Source: Authors.
Note: Figures are the shares of communities that reported the availability of tractors, weighted by the number of households and sample weights of the communities.

Table 2.15 summarizes the average ratio of tractor rental price to labor wages in each agroecological zone for households with various mechanization statuses. The tractor-rental-price-to-wage ratio has declined in all agroecological zones; between 1995 and 2010, it declined by almost 30 percent (5.4 to 3.8 in the Terai, for example), with about two-thirds of such decline occurring between 2003 and 2010. This is consistent with the real wage increases observed in these zones during this period (Table 2.10), indicating that the decline in the rental-price-to-wage ratio has been mostly driven by real wage increases, rather than a decrease in real rental price.

On a minor note, in the Terai, where a majority of tractor owners are located, those owners have tended to be in communities where tractor rental prices have been relatively higher than in the rest of the communities. This is consistent with the hypothesis that investments in tractors may be partly driven by the motive to earn a profit from renting them out.

These patterns are consistent with the hypothesis that in the Terai, tractor rental markets have been relatively efficient and the relative cost of tractor rental to wage rates has generally determined the uptake of tractor hiring services.

Table 2.15 Ratio of tractor rental price (hour) to wage (day)

Ecological belt	1995					2003					2010				
	All	Tractor Owner	Tractor renter	Draft animal users	Non-mechanized	All	Tractor Owner	Tractor renter	Draft animal users	Non-mechanized	All	Tractor Owner	Tractor renter	Draft animal users	Non-mechanized
Terai	**5.4**	**5.4**	**4.9**	**5.0**	**5.4**	**4.9**	**6.0**	**4.9**	**4.9**	**5.1**	**3.8**	**4.2**	**3.7**	**3.9**	**3.7**
Hills	4.9	4.3	3.1	5.1	4.9	4.5	3.7	3.1	4.6	4.3	3.5	1.8	2.6	3.7	3.4
Mountains	4.9	NA	NA	5.1	4.8	4.5	NA	NA	4.5	4.8	3.5	5.1	2.5	3.5	3.6

Source: Authors.
Note: NA = Not available.

Tractor Investments and Hiring-Out Services

Not all tractor owners, however, seem to hire out. Tractor hiring-out services are provided by approximately half of tractor owners, although the standard errors of the estimated shares are large due to the small sample of tractor owners, particularly in 2003 (Table 2.16). These shares have remained fairly constant in the Terai as well as in the whole of Nepal between 2003 and 2010. As is shown in the next section, tractor hiring out accounts for a relatively small share of household total revenue, which may explain why only half of the owners hire out tractors. This is interesting because tractor prices were typically in the range of 400,000 rupees in 2010, or worth 25 metric tons of cereals (Table 2.17), with typically 30 horsepower (Justice and Biggs 2013),4 which is still substantial for most households in Nepal including tractor-owner households.

Table 2.16 Percentage of tractor owners earning revenue from hiring out

Ecological belt	Year	
	2003	2010
Terai	50 ± 33	57 ± 18
All	56 ± 27	57 ± 16

Source: Authors.

Table 2.17 Per unit tractor prices, assessed from current market prices—average

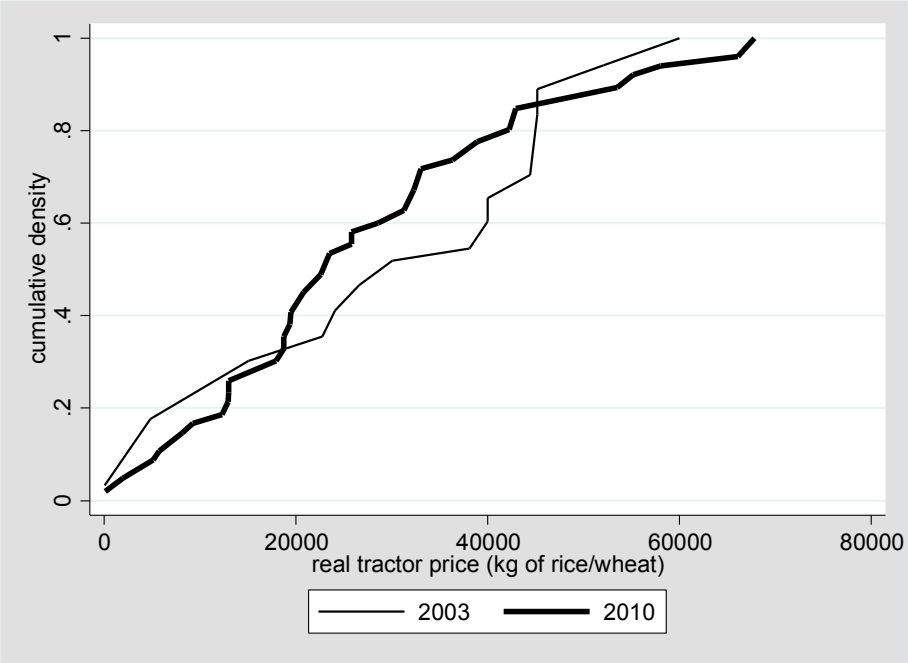
Unit	Year		
	1995	2003	2010
Nominal rupee—mean		285,849	436,088
Nominal rupee—median		300,000	400,000
Real price in metric tons of cereals—mean	NA	35.0	26.4
Real price in metric tons of cereals—median	NA	37.5	23.7
Average number of tractors owned	1.0	1.2	1.1

Source: Authors.
Note: NA = not available.

The real price of a typical tractor, measured in metric tons of cereals, declined by 30 percent between 2003 and 2010, although the nominal price increased. It is not clear how much of such change is due to the shift to smaller tractors during the period, as the NLSS does not report the type of tractor owned. The distributions of real tractor prices (Figure 2.6) did not change significantly. Such insignificance, however, may be due to the small sample size of tractor owners, as the real price of a median-range tractor seems to have declined slightly from 2003 to 2010. This pattern may have accelerated after 2010, when the number of power tillers in Nepal started growing (Table 2.18). The fixed investment needed for a typical tractor must have declined slightly during this period, possibly leading to the increase of tractor owners between 2003 and 2010 (1 to 2 percent of farm households in Table 2.2).

[4] In Kathmandu, tractor models like MF 1035DI, Mahindra 275, and so on were widely observed during the authors' field visits in April 2014.

Figure 2.6 Change in distribution of (real) tractor prices, the Terai, 2003 and 2010



Source: Authors.
Note: *p*-value (H_0: distributions are equal) = 0.222 (Kolmogorov–Smirnov test).

Table 2.18 Number of four-wheel tractors and power tillers in Nepal

Type of machinery	Year				
	1989	1992	2005	2010	2013
Four-wheel tractors	5,066	6,464		30,000	
Power tillers	1,100	1,300		12,000	20,000
Mini-tillers			500		5,000[a]
Share of power tillers (%)	18	17		29	

Source: CSAM (2014) for figures in 1989 and 1992; Justice and Biggs (2013) for figures in 2010 and 2013.
Note: Figure for mini-tillers is for 2015, based on personal communications with mini-tiller dealers.

3. HOUSEHOLD TYPES AND TRACTOR-USE STATUS IN THE TERAI

Whereas the Nepal Terai is relatively homogeneous in terms of agroecological environment, the economic characteristics of households vary. Distinct differences in household characteristics across tractor-ownership status or tractor-use status can suggest whether mechanization is a significant component of household livelihood change. The extent of such differences can suggest whether mechanization growth is economically significant in the development process.

The NLSS is particularly suitable in assessing such typological aspects as it has information on various economic activities and farming practices employed by the households. In this section, we asses household types from the following perspectives. First, we classify Terai households according to their economic activities. In particular, we look at what shares of households rely on each activity as a primary source of revenue. We then assess whether crop revenue (including subsistence production) is still the largest revenue source for most types of households. If not, the effects of mechanization on crop revenue may have less economic significance in the overall economy. We then classify farm households by production practices (input cost shares) and the production values of different combinations of crops. We then assess their associations with mechanization status.

Characteristics of Households by Tractor-Use Status

Table 3.1 summarizes the key characteristics of households by farming status, as well as tractor-use status. The revenues include the value of subsistence production of crops and livestock evaluated at local market prices and deflated by the local cereal prices. Revenues, expenditures, and assets are expressed as proportions to the levels in 1995, so they can only be comparable within each category and across years, but not across categories. Some key patterns are observed:

- Consistent with conventional wisdom, farm households generally earn a smaller total revenue and consume less than nonfarm households do. At the median and mean, real per capita revenue and expenditures in 2010 differ by 2 to 3 times and 1.5 to 2 times, respectively. There is, however, large heterogeneity in total revenue within each type of household. This is particularly so among nonfarm households. This is largely due to the high heterogeneity in revenue from nonagricultural enterprises.
- Within farm households, tractor-owner households earn and consume substantially more and own substantially more assets than other farm households. The differences seem to be expanding over time. In 2010, their median and mean revenues, expenditures, and asset values are about 4 to 6 times higher than the levels of all farm households. Tractor owners' growth in revenue, consumption, and assets also far exceed those of nonfarm households.
- Differences between tractor renters and draft-animal-only users are much smaller relative to those with tractor owners. Tractor renters, however, enjoy revenues, consumption, and assets that are typically 20 to 50 percent higher than those of draft-animal-only users.
- Nonmechanized households' revenues and assets are typically much lower than those of other farm households. However, they become highly heterogeneous toward 2010.
- About 50 percent of farm households sell their crops, and 63 percent sell either crops or livestock products. These shares are higher among tractor owners, followed by tractor renters and draft-animal-only users. Nonmechanized farm households are mostly subsistence.
- Tractor-owner households tend to be of a larger size compared with other farm households, although the differences have narrowed over time. Working-age members in nonfarm households are better educated than those in farm households, completing two years longer of education. Working-age members in tractor-owner households have become increasingly educated, completing an average of 6.7 years, substantially higher than the rest of the farm households.

Table 3.2 compares households' access to various facilities. Patterns are generally intuitive: nonfarm households have significantly better access, and access generally improved between 1995 and 2010, shortening the time required to the facilities. It is not yet clear whether that is due to migration to urban areas or to improved infrastructure. Tractor renters also have generally better access than draft-animal-only households and nonmechanized households. Access characteristics have changed most among tractor owners. In 1995 and 2003, they tended to be located in more remote areas, compared with tractor renters in particular. Between 2003 and 2010, more tractor owners emerged in suburban areas or areas where access had improved (closer to various facilities than nonowners, unlike in 2003). Much growth in tractor ownership between 2003 and 2010 therefore occurred in relatively suburban areas instead of remote farm areas.

Table 3.1 Household characteristics in the Terai by mechanization status (including landless farming households)

Category	Statistics	1995						2003						2010						
		Non farm hhds	Farm households					Non farm hhds	Farm households					Non farm hhds	Farm households					
			All	Tr owner	Tr renter	Dr animal	Non-mech		All	Tr owner	Tr renter	Dr animal	Non-mech		All	Tr owner H	Tr owner L	Tr renter	Dr animal	Non mech
% of population (households)		6	94	1	7	9	78	10	90	1	25	46	18	19	81	1	1	36	32	13
Real revenue per capita[a,b]	Median	39	49	99	89	49	49	118	59	296	99	59	20	168	99	611	394	128	89	59
	Mean	276	89	237	138	79	89	1233	158	306	197	158	99	759	276	1055	483	296	197	375
Real expenditure per capita[a,b]	Median	114	76	133	101	82	70	190	108	222	139	101	95	190	139	463	298	152	120	133
	Mean	177	95	253	152	108	89	304	158	304	190	146	127	317	190	894	469	203	158	177
Real per capita asset value [a,b]	Median	21	43	119	119	33	40	95	70	388	134	70	17	148	147	994	670	234	106	58
	Mean	95	100	286	197	86	91	286	161	555	222	155	75	819	463	2061	2227	523	340	417
% selling crops		0	35	48	64	31	33	0	54	90	76	58	12	0	50	89	96	64	47	13
% selling crops or livestock products		0	51	48	80	51	49	0	61	90	80	68	18	9	63	89	96	76	64	21
Household size		4	6	10	7	6	6	4	6	8	6	6	5	4.0	5	6	5	5	5	5
		4.7	6.6	9.5	8.3	5.8	6.5	4.8	6.2	10.6	6.4	6.5	6.1	4.6	5.4	6.8	6.1	5.7	5.4	5.1
Working-age member		2	3	4	4	2	3	2	3	5	3	3	3	2	3	4	3	3	3	2
	Median	2.6	3.3	4.6	4.1	2.7	3.2	2.8	3.2	5.5	3.8	3.1	3.1	2.7	3.0	4.0	3.6	3.2	2.9	2.8
Years of education (working-age member)		3.9	2.2	3.6	4.0	2.0	2.0	6.6	3.0	5.0	3.6	2.7	2.1	6.1	4.0	6.7	6.7	4.5	3.4	3.3

Source: Authors.

Note: Missing observations are excluded. hhds = households; Tr = tractor; Dr = draft. Tr owner H = tractor owners with tractors worth the value of 20,000 kilograms of rice/wheat or more; Own L = tractor owners with tractors worth less than the value of 20,000 kilograms of rice/wheat. a Figures include subsistence food consumption evaluated at real market values. b National average in 1995 = 100.

Table 3.2 Time (minutes) to nearest facility in the Terai (including landless farming households)

Category	1995						2003						2010						
	Non farm hhds	Farm hhds	Tr owner	Tr renter	Dr animal	Non-mech	Non farm hhds	Farm hhds	Tr owner	Tr renter	Dr animal	Non-mech	Non farm hhds	Farm hhds	Tr owner H	Tr owner L	Tr renter	Dr animal	Non-mech
Agricultural center	40	79	96	74	73	80	29	63	71	54	69	64	31	56	32	40	49	61	60
Bank	42	88	109	76	78	90	28	88	78	74	93	94	22	70	34	41	57	78	84
Bus station	36	65	68	55	67	65	14	38	38	32	41	38	10	35	9	16	24	43	47
Cooperative	36	73	84	63	65	74	27	61	62	52	69	56	27	53	28	33	49	58	49
Market center	40	83	65	74	80	85	21	64	65	57	68	64	25	60	29	38	54	65	58
Phone							8	35	45	28	40	31	6	21	8	18	10	26	34
Paved road	35	90	115	79	88	91	16	63	57	50	68	70	12	53	23	19	41	62	59
Shop	13	25	19	9	15	28	2	9	11	7	11	7	1	5	0	2	3	7	3

Source: Authors.

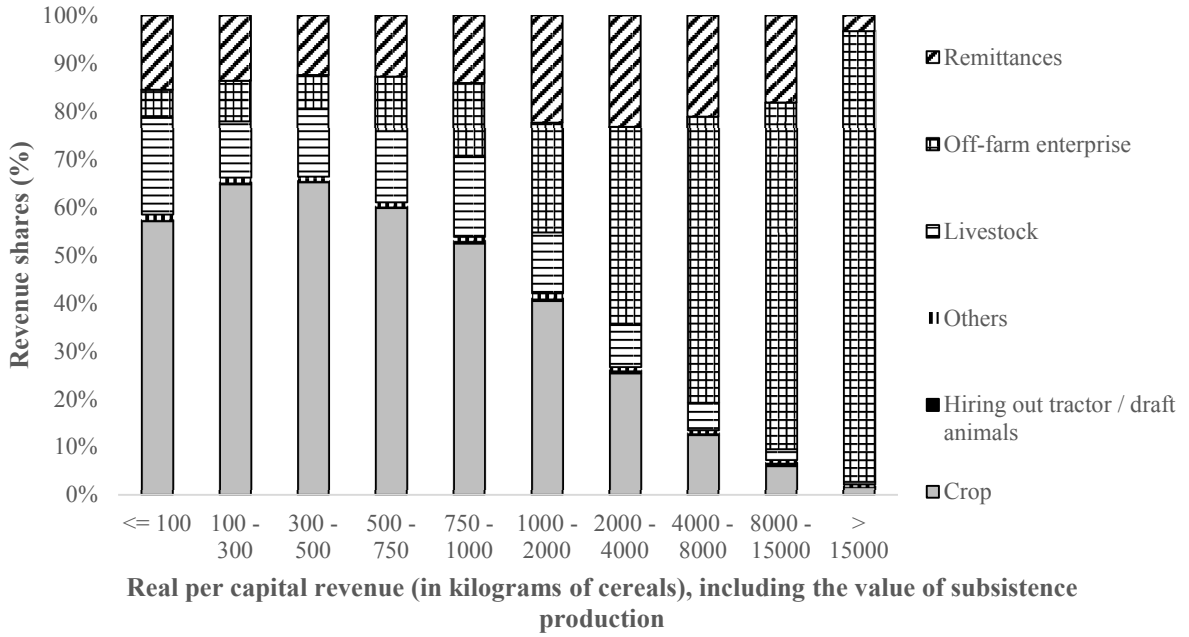
Note: hhds = households; Tr = tractor; Dr = draft.

Household Typology by Economic Activity (Revenue)

Breakdown of Revenue by Source

Total revenue (including the values of subsistence crop and livestock production) in the Terai between 1995 and 2010 can be roughly decomposed into (1) crop production; (2) livestock production; (3) off-farm enterprises; and (4) remittances. Contributions of each of these sources differ depending on the overall size of revenue. Figure 3.1 illustrates how the breakdowns change as overall revenue increases (measured by real per capita household revenue). For households with low overall revenue, crop production is the dominant source, contributing up to half to two-thirds of all revenue. Its share declines as overall revenue rises. Livestock follows the same pattern. Revenue shares of remittances are generally constant, but slightly higher for households with medium revenue levels. Revenue shares of off-farm enterprises dominate for high-revenue households. Revenue from the hiring out of tractors or draft animals remains small at all levels.

Figure 3.1 Revenue shares from different sources at different levels of real per capita revenue (including subsistence production)



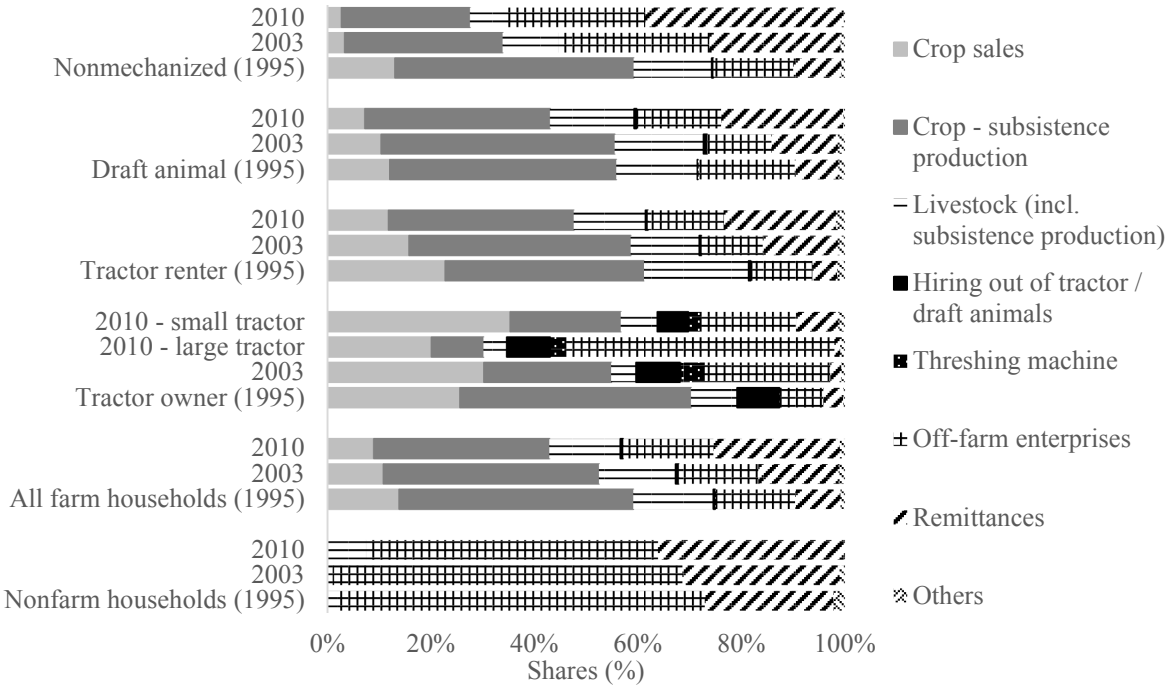
Source: Authors.

Figure 3.2 illustrates similar breakdowns and their changes over time, differentiated by households' farming and mechanization status. Key patterns are the following:

- For tractor owners, large sources of revenue have been crop sales and nonagricultural enterprises. Revenue from nonagricultural enterprises seems to be growing faster for them, with divergence in revenue, and gradually overtaking such revenue for nonfarm households. Revenue from tractor hiring out is generally much smaller than the value of crop production (on average 6 percent of total revenue including the value of crop production; sample maximum in the Terai in 2010 was 35 percent).

- Neither type of farm household (tractor renter or nonuser) has experienced growth in crop sales revenue, although tractor users are consistently more likely to be selling crops; crop sales account for a small share of total revenue. This indicates that growths in tractor use may be occurring without substantial commercial growth.
- Generally, receipts of remittances are growing and overtaking crop sales revenue for most farm households except tractor owners. Crop production, however, still dominates for mechanized households if the value of subsistence production is included.

Figure 3.2 Breakdown of revenue by source (economic activity) and by farming/mechanization status



Source: Authors.
Note: Figures are averages of shares, rather than shares of averages. If shares of averages are used, the share of off-farm enterprises becomes much larger because of its positive correlation with total revenue.

Simple Typology of Households Based on Major Revenue Sources

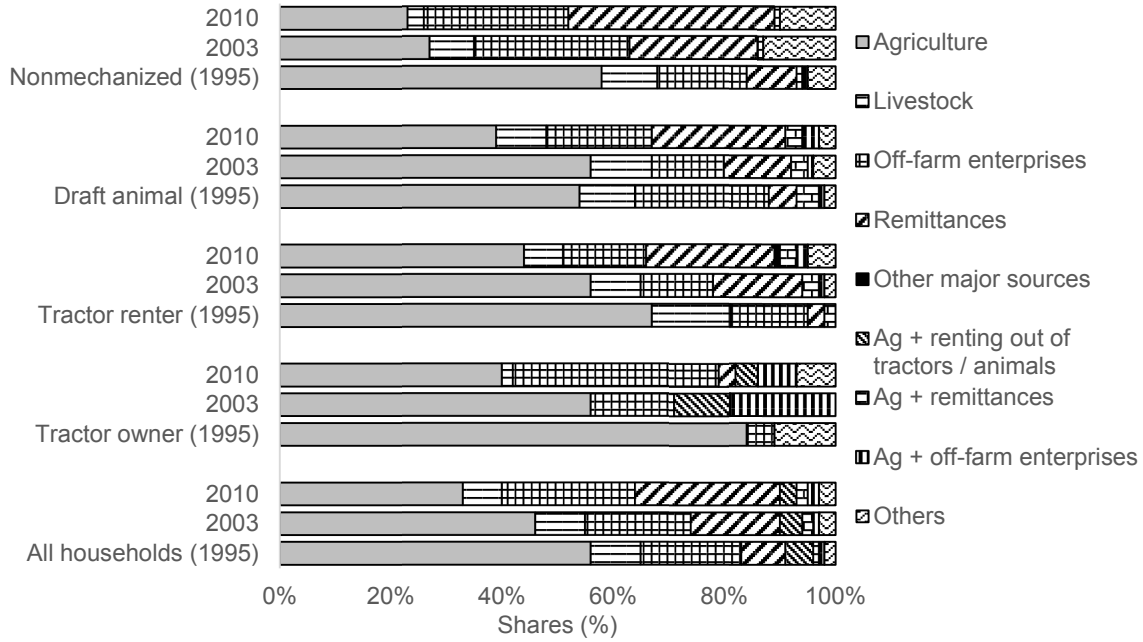
A household's economic characteristics can be in one way affected by which activity or source it derives is greatest revenue or value from. Here, we classify the Terai households by such criteria, and assess how they have changed between 1995 and 2010, and how this is associated with farming and mechanization status.

Figure 3.3 summarizes the distribution of Terai households based on this classification. Major types of households are the following:

- Agricultural household—Value of crop production, including horticultural and other crops, accounts for more than half of total revenue.
- Livestock household—Value of livestock production accounts for more than half of total revenue.
- Remittee household—Gross amount of remittances received accounts for more than half of total revenue.

- Off-farm enterprise (OFE) household—Gross revenue from off-farm enterprises accounts for more than half of total revenue.
- Mechanization service provider agricultural household—Mechanization service provision and crop production are the two largest revenue sources, but neither accounts for more than half of total revenue.
- Remittee agricultural household—Remittances and crop production are the two largest revenue sources, but neither accounts for more than half of total revenue.
- OFE agricultural household—Off-farm enterprises and crop production are the two largest revenue sources, but neither accounts for more than half of total revenue.

Figure 3.3 Distribution of household types by the largest sources of revenue (including the value of subsistence crop production), the Terai



Source: Authors.

Generally the most common type is the agricultural household, but its share has declined from 56 percent in 1995 to 33 percent in 2010. OFE households have consistently accounted for approximately 20 percent of households, while the share of remittee households increased from 8 to 26 percent between 1995 and 2003. Growth of the remittee household share is largely due to increases in gross remittances received, rather than a decrease in crop revenue.

Among farm households, these distribution patterns are commonly observed across most households, regardless of mechanization status. Among tractor owners, the agricultural household share has declined from 84 to 40 percent, while OFE households have emerged to account for 37 percent. Mechanization service provider agricultural households and OFE agricultural households account for most of the remaining shares, while remittee households are rare.

The breakdown of types and associated trends are similar among tractor-renter households and draft-animal-user households, indicating that tractors may simply substitute for draft animals and the switch from the latter to the former may not substantially change a household type, although this needs to be more formally investigated in future studies.

The breakdown of types and the trends are also broadly similar with nonmechanized farm households, except that the shares of OFE households and remittee households have increased much faster among these households, largely replacing agricultural households.

Farm Household Typology and Mechanization in the Terai

The descriptive analyses in previous sections roughly suggest that, in the Terai, tractor owners are those specializing in commercial crop production, and that despite the increase in remittances, crop production is still one of the major sources of revenue for households, particularly for mechanized households using tractors or draft animals.

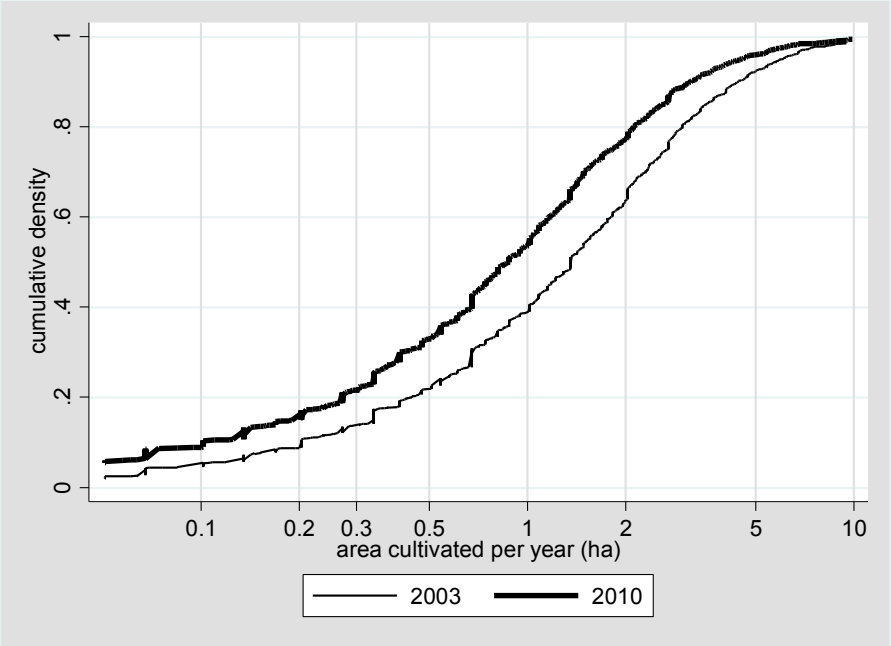
Here we further assess the types of farm household. Again using a simple approach, we examine input use patterns and crop combinations and how they vary based on farm size. The objective is to obtain a rough understanding of how mechanization status is associated with production scale, input use, and crop combinations.

Production Scale, Input Use Intensity, and Tractor Use

Figure 3.4 illustrates the distribution of farm size in the Terai based on the cultivated area per year. Figure 3.5 illustrates the share of area cultivated by farm households based on the farm sizes in Figure 3.4. Eighty percent of farm households cultivated less than 2 hectares in 2010, and farm size per farm household has declined along the entire distribution (Figure 3.4).5 In terms of the share of cultivated area, farms cultivating more than 2 hectares still account for 60 percent of the total area cultivated in the Terai (Figure 3.5). Therefore, the mechanization patterns for both small-scale farmers and medium-to-large-scale farmers have important implications for farm household welfare as well as agricultural production in the Terai.

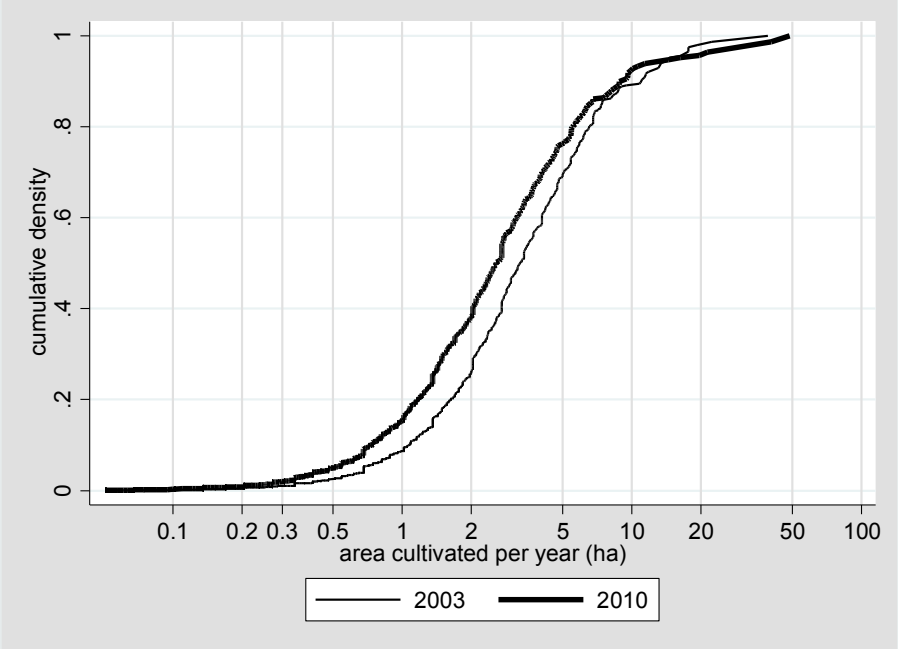
[5] However, as was discussed in Table 2.7, because working-age household members have also declined during this period, the cultivated area per working-age household member has actually slightly increased.

Figure 3.4 Distribution of annual cultivated area, the Terai, 2003 and 2010



Source: Authors.
Note: Figures are among landed households, and exclude landless farm households.

Figure 3.5 Shares of cultivated area by operational size of farm household, the Terai, 2003 and 2010



Source: Authors.

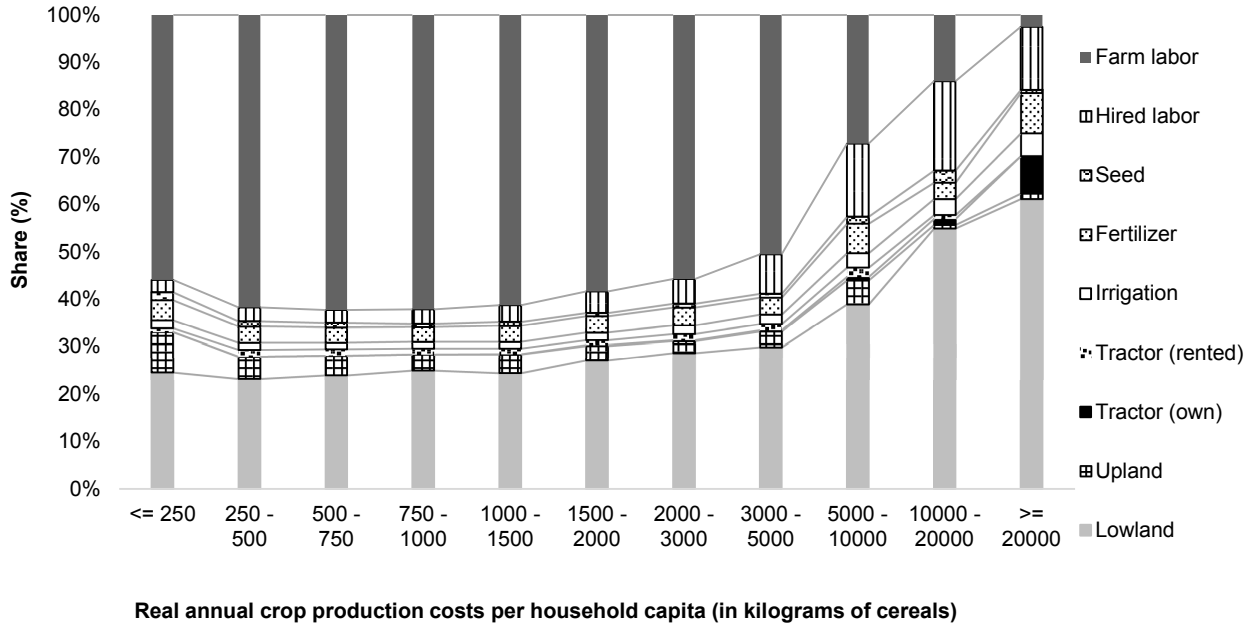
Figures 3.6 and 3.7 illustrate the cost shares of different production inputs in total production costs, differentiated by total production cost per capita and by the size of the cultivated area. The cost of land use is approximated by the farmland rental costs reported by the households (differentiated by lowland and upland).6 Similarly, irrigation costs were imputed based on the irrigation cost per unit of area multiplied by the irrigated areas. Figure 3.8 shows the shares of landed farm households using fertilizer and tractors, and how they vary by size of cultivated area. Figure 3.9 illustrates the Coefficient of variation of selected input costs, by cultivated area in 2010. The following general patterns are observed:

- Tractor rental costs generally account for only a small share of total production costs, relative to other inputs including land and labor. This pattern possibly reflects generally small-sized landholdings in the Terai belt. Production is land saving and input intensive, but still an increasing number of households use tractors. The renting of tractor services is mostly replacing just a small share of labor activities (either land preparation or transporting harvest).
- For small-to-medium-size farmers, the cost share of tractor use is fairly proportional to the overall production cost (particularly for those cultivating 0.2 to 10 hectares in Figure 3.7, more than 80 percent of households, or those incurring per capita production costs worth less than 5,000 kilograms of cereals in Figure 3.6). For these households, tractor rental is scale neutral—the availability of tractor rental does not induce scale expansion. The use of a tractor rental service may be similar to using fertilizer, in the sense that it is fairly proportional to the land cultivated and almost scale neutral. Although more formal investigation is required, this is consistent with the hypothesis that the production function is fairly homothetic for these small-to-medium-scale households. The intensity of tractor rental is generally associated with the intensity of other inputs (including labor and fertilizer); the adoption of rented tractor services is happening along with the process of general production intensification in terms of both land and labor saving.
- The scale effects from renting tractor services seem limited; such rental does not usually transform production systems—only owners seem to exploit scale effects.
- Scale effects are observed only in comparison with extremely small-scale farmers, as well as very large farmers. The share of farm households using tractors is much lower below the cultivated area per year of 0.2 hectare (about 10 to 20 percent, compared with approximately 50 percent in Figure 3.8). The share of tractor-use costs increases (but still is lower than fertilizer) only for very large farmers (cultivating 20 or more hectares annually) or intensive input users (incurring a per capita production cost worth more than 20,000 kilograms of cereals annually).

Importantly, however, tractor-use costs are slightly more heterogeneous than other inputs. Figure 3.9 shows the coefficient of variation (CV) of the costs of major inputs among each group of households based on cultivated area (equals standard deviations of input costs divided by the average input costs among each group of households). A high CV indicates greater heterogeneity in the use of those inputs. The relatively high CV for tractor-use costs possibly indicates higher substitutability between tractor rental services and other inputs such as hired labor (thus high heterogeneity in tractor rental costs within each cohort). However, as mentioned above, since the general cost share of tractor rental costs is small, absolute heterogeneity is also small (only relative heterogeneity—such as the CV).

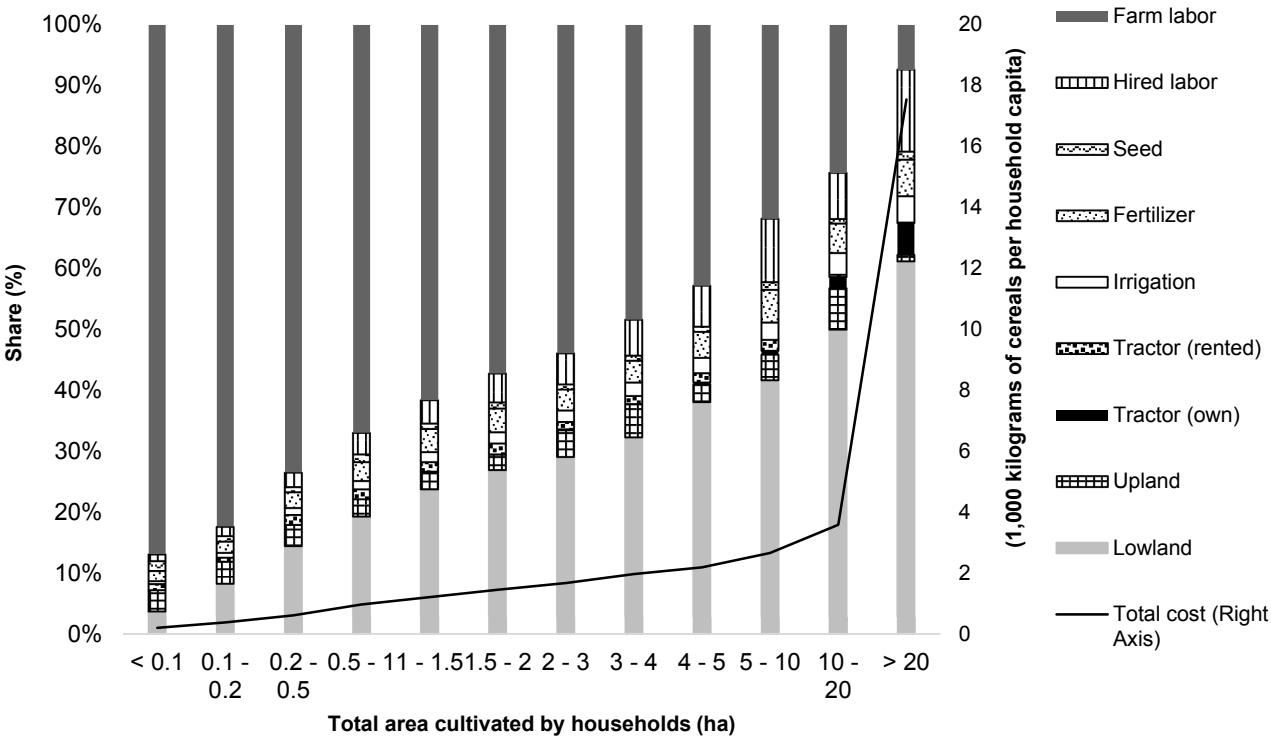
[6] While only a fraction of households reported the cost of renting per unit of land, most households reported the expected sales/purchase prices of other plots owned. Using the ratios of rental costs and expected sales costs, we extrapolated the rental costs for plots whose rental costs were not reported.

Figure 3.6 Production cost shares in the Terai, by total cost per household capita (average over three survey rounds)



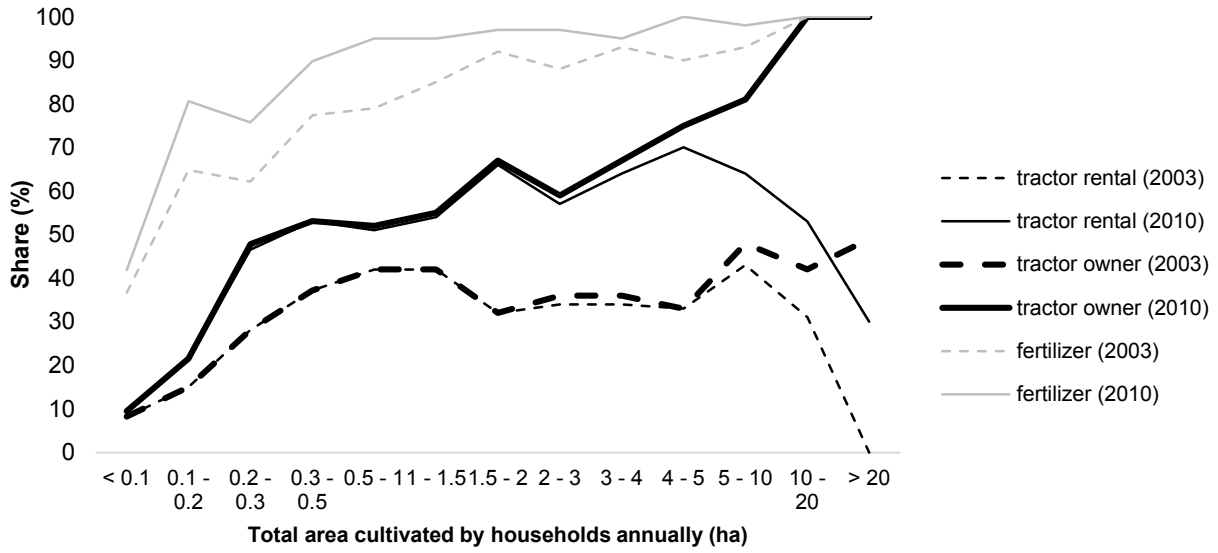
Source: Authors.

Figure 3.7 Production cost shares in the Terai, by cultivated area, average over 2003–2010



Source: Authors.

Figure 3.8 Share of landed farm households in the Terai using tractors and fertilizer, by cultivated area



Source: Authors.

Figure 3.9 Coefficient of variation of selected input costs, by cultivated area, the Terai

Source: Authors.

Farm Household Typology in the Terai—Crop Production Scale

Here we classify Terai farm households based on crop combinations and assess the association with mechanization status. Similar to the above classification based on revenue from economic activities, we simply identify the dominant crops based on their production values.

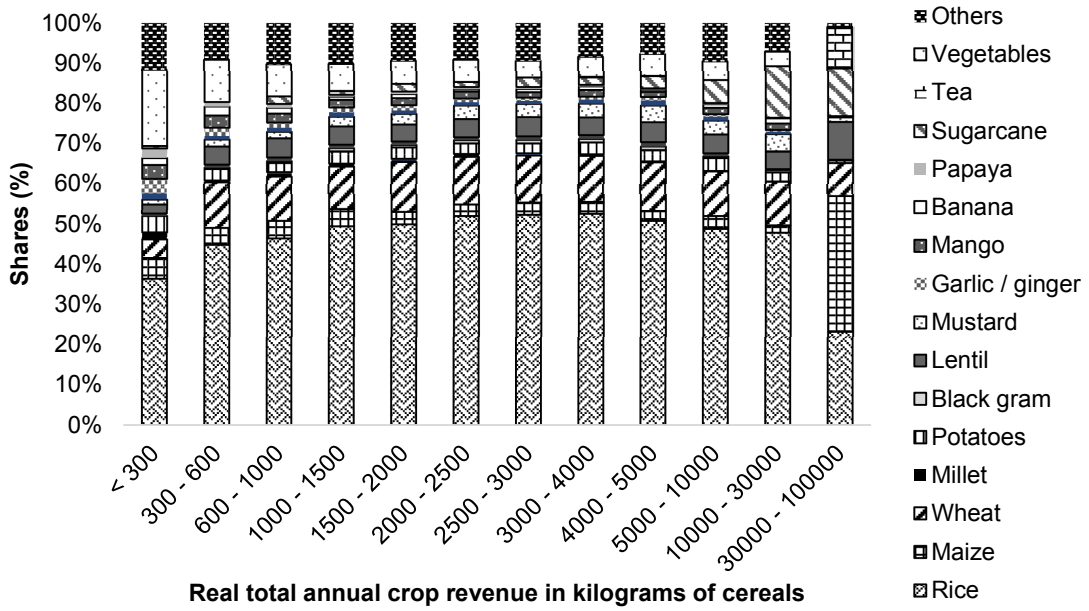
Figure 3.10 illustrates the breakdown of total crop revenue (including the value of subsistence productions) across crops and how that breakdown changes as the total crop revenue increases. Generally in the Terai, the value of rice accounts for about half of total production value, followed by wheat, which generally accounts for 10 to 15 percent. Vegetables account for a greater share among small-scale producers (particularly those producing a value worth less than 600 kilograms of cereals), while sugarcane accounts for a greater share among medium-to-large-scale commercial producers (particularly those producing a value of more than 5,000 kilograms of cereals). Figure 3.11 illustrates similar revenue shares by cultivated area. The patterns are fairly similar to those in Figure 3.10.

Generally, the average combination of crops is fairly constant regardless of production scale, except for a fraction of extremely small-scale farmers and large-scale farmers. Among households cultivating 0.2 to 5 hectares (about 80 percent of farm households) or producing values worth 300 to 10,000 kilograms of cereals, the revenue breakdown across crops is fairly constant regardless of scale.

Whereas Figures 3.10 and 3.11 are based on averages within each cohort, Figure 3.12 shows the breakdown of types of farm households based on dominant crops grown. Solid colors indicate households that earn more than half of their total production value from a single group of crops, and are thus more specialized. Nonsolid (patterned) colors indicate households that are not specialized in this sense (no single group of crops accounts for more than half of total production value) but earn the largest value from either rice and wheat, rice and pulses, or rice and vegetables. For example, among households cultivating less than 0.1 hectare per year, approximately 20 percent earn more than half of the total production value from rice, another 20 percent of households earn more than half of total production value from vegetables, about 3 percent earn the largest value from rice and wheat combined although neither accounts for more than half, and so on.

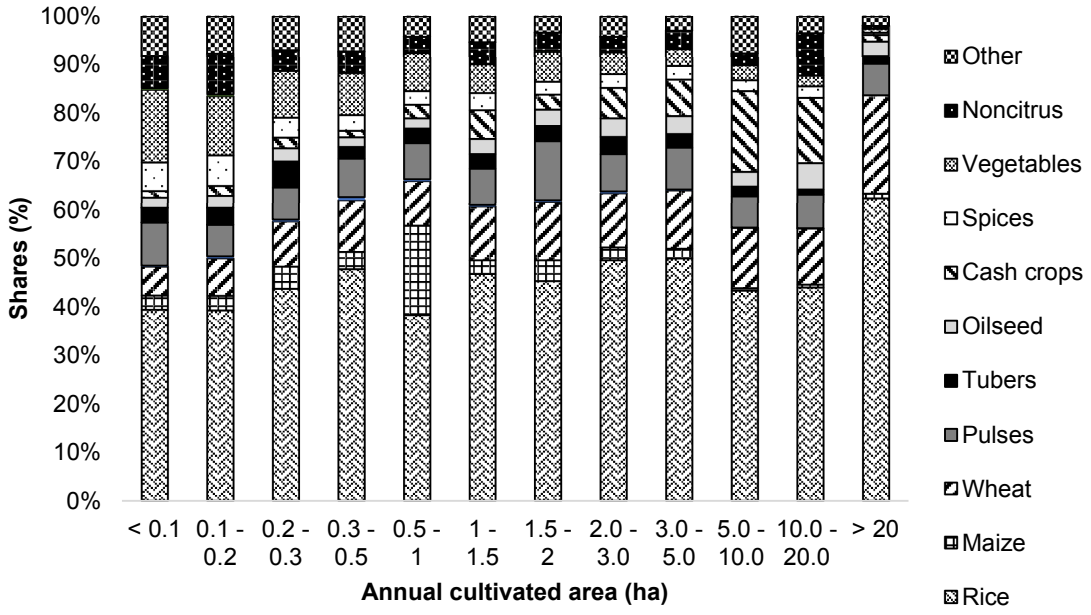
Generally about 40 to 50 percent of farm households are specialized rice producers and 20 percent are rice/wheat producers for households cultivating between 0.2 and 10 hectares. Some specialized cash crop producers are found among medium-scale farmers. Specialized vegetable producers are found among extremely small-scale farmers. Overall, except for extremely small-scale producers, distribution patterns of the types of farm households are relatively constant across production scales.

Figure 3.10 Production scale and revenue share of crops (including subsistence production), by real total annual crop revenue, the Terai



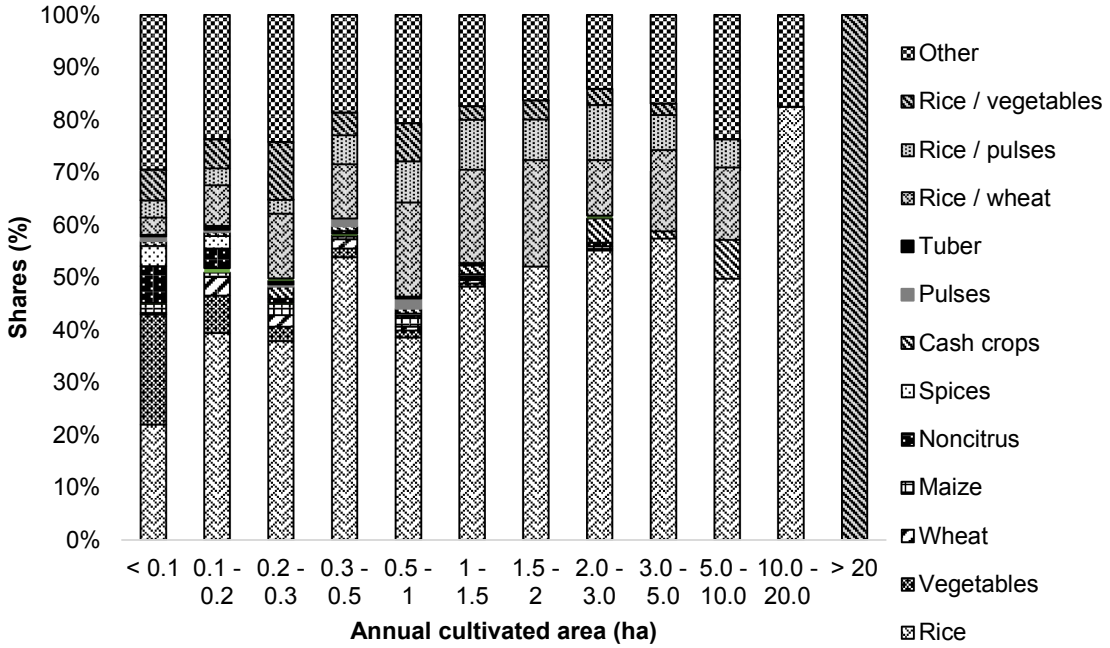
Source: Authors.

Figure 3.11 Share of crops to total crop revenue (including subsistence production), by cultivated area, the Terai



Source: Authors.
Note: Cash crop = sugarcane, tobacco, jute.

Figure 3.12 Farm household types by crop, by cultivated area, the Terai, average of 2003 and 2010

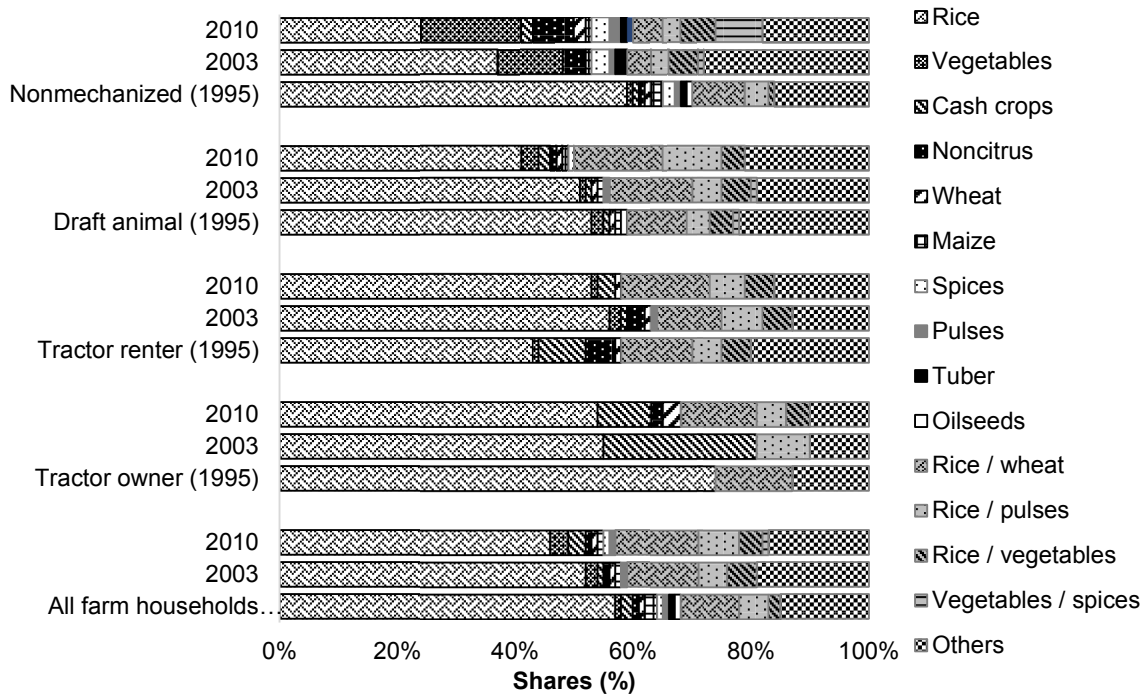


Source: Authors.
Note: Figures indicate the share of households earning more than half of crop revenue (including subsistence production) from each group of crops.

Figure 3.13 shows the breakdown of farm household types based on mechanization status, and how it has changed over time between 1995 and 2010. The share of specialized farm households has been higher among tractor owners, generally accounting for 70 to 80 percent. Most have been specialized rice producers. Ten to 20 percent have been specialized cash crop producers, although their shares have declined toward 2010, replaced by rice/wheat producers.

The breakdown by type has been generally similar among tractor renters and draft animal users, although by 2010 the share of specialized rice producers had declined modestly among draft animal users. While tractor renters are slightly more likely to participate in the market and sell crops than are draft animal users (Table 3.1), the level of crop specialization or diversification does not seem to differ between them. This is in contrast to evidence in southern India, where market participation is associated with greater diversity of crops grown (Takeshima and Nagarajan 2012).

Figure 3.13 Distribution of household types by crop and mechanization status (including the value of subsistence crop production), the Terai



Source: Authors.

4. INTENSIFIED USE OF EXTERNAL NONLAND INPUTS: TYPOLOGY IN THE TERAI

The use of tractors seems to help raise cultivation intensity compared with draft animals only, both the use of land and per unit of land, albeit to a limited extent. Table 4.1 shows real expenditures per cultivated land for each of the external nonland inputs, measured in kilograms of cereals per hectare, by farm households that rent tractors and those that use only draft animals. For example, farm households owning 0.1 to 2.5 hectares of land and renting tractors used fertilizer that was worth 208 kilograms of cereals per hectare of cultivated area, which was statistically significantly higher than 150 by draft-animal-only users. Similar patterns hold for hired labor. Altogether, tractor-renter households use external inputs worth 759 kilograms of cereals per hectare, approximately 60 to 70 percent more than draft-animal-only users. While these differences are offset by the lower use of family labor (1,853 versus 2,243) and overall input use intensity is similar (2,612 versus 2,698), the more intensive use of external inputs indicates land-saving modernization. These patterns are generally consistent over time and across the regions.

Table 4.1 Differences in input use per cultivated area between tractor renters and draft-animal-only users in the Terai, 2010 (kilograms of cereals/hectare)

Type of farm household		Farm households with own farm size 0.1 to 2.5 (ha		All farm households	
		Tractor renters	Draft animal users	Tractor renters	Draft animal users
Input use per cultivated area (equiv. to kilograms of cereal/ha)	Fertilizer	208*	150	194*	152
	Hired labor	260*	170	266*	187
	Use of external inputs per cultivated area (excluding tractor)	628*	454	617*	470
	Tractor use per cultivated area	131*	0	124*	0
	All external inputs	759*	454	741*	470
	Farm labor	1,853*	2,243	1,626*	2,220
	Input use per cultivated area (excluding land)	2,612	2,698	2,367	2,690
Mean cultivated area per year (ha)		1.5*	1.2	1.7*	1

Source: Authors.

Note: Figures are weighted by sample weights and cultivated areas. Asterisks indicate statistically significant difference based on *t*-test: * 5%.

Growing tractor rentals and the larger areas cultivated by tractor renters compared with draft-animal-only users (bottom row, Table 4.1) may give the impression that tractor use is associated with farm size expansion instead of land-saving modernization, but the rather sluggish land investment behavior suggests that that is not likely the case. Tractor renters cultivated significantly more area than draft animal users in 2010, but that was mostly due to the selective adoption of tractors (more intensive adoption by larger landowners). The positive correlation in tractor rental and size of cultivated area is rather because more households with greater owned land adopted tractors between 2003 and 2010 (Figure 2.3; Table 4.1). For example, there is little sign of selective land investment behavior; about the same fraction of both tractor renters and draft animal users sold or purchased land in 2009 (Table 4.2).

Descriptive statistics in previous sections suggest substantial variation as to which of these inputs is more intensively used, and consequently as to the adoption intensity of tractors. In this section, we construct a typology of such intensification among farm households in the Terai. Farm households of a similar type "constitute the so-called recommendation domains, a group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation" (Köbrich, Rehman, and Khan 2003, citing Byerlee et al. 1980). Understanding the typology is important "when heterogeneity and interactions of agents and environments are significant and, therefore, policy responses cannot be aggregated linearly" (Berger, Schreinemachers, and Woelcke 2006).

Table 4.2 Percentage of farm households transacting land in 2009, differentiated by their mechanization status in 2010, the Terai

	Tractor owners	Tractor renters	Draft animal users	Other households
Sold	31 ± 18	5 ± 2	4 ± 2	2 ± 2
Purchased	7 ± 10	7 ± 2	6 ± 2	4 ± 3

Source: Authors.

Note: Figures after ± are 95% margin of error based on symmetric assumptions and adjusted for village development committee cluster.

A typology can be constructed across various dimensions. Some studies focus on the behavioral aspect, while others focus on the correlation between behaviors and exogenous resource endowments as well as welfare status (Dorward 2006; Takeshima and Edeh 2013; Takeshima, Nin Pratt, and Diao 2013; Takeshima 2016). Here, we focus only on the behavioral aspect, that is, what types of intensification behaviors are observed. This is because, in the case of the Terai belt, discussions in previous sections have indicated that variations in endowments and welfare status are largely determined by the size of farmland owned. We therefore limit the types of variables used in the cluster analysis to behavioral variables only, unlike in the aforementioned studies, which also include endowment variables. Table 4.3 lists the behavioral variables, the selection of which is based on the descriptive analyses in previous sections. For example, we focus on external nonland inputs (own tractors, rented tractors, fertilizer, irrigation, purchased seeds, and hired labor) because the overall patterns of the costs of family labor use and land use are determined by the operational scale, and family labor use is generally more stable given the operational scale (Figure 3.9). The substitution of hired labor for family labor also reflects the transformation of agricultural labor use. The growth of that substitution implies that farm households are increasingly exploiting the efficiency improvements of labor resource use through labor force allocations across space and time through the labor market.[7]

Table 4.3 Variables used to classify intensification patterns of external input use per cultivated area

Variable	Use
Cost of external inputs per owned farmland (natural log)	
Cost of family labor used in farming per owned farmland (natural log)	
Share (%) of lowland among total farmland cultivated annually	
Cost share (%) of each major external nonland input	Own tractors Rented tractors Fertilizer Irrigation Purchased seeds Hired labor
Share (%) of crop revenue from each major crop (including imputed value for subsistence production)	Rice Maize Wheat Lentil Sugarcane Vegetables

Source: Authors.

Here, the typology is constructed following the modified cluster analysis method proposed by Punj and Stewart (1983) and Siou et al. (2011) and implemented in Takeshima and Edeh (2013), Johnson, Takeshima, and Gyimah-Brempong (2013), and Takeshima, Nin Pratt, and Diao (2013), which combines

[7] This also includes the farm household's decision to send some family members into the nonagricultural sector or abroad when they have a better prospect of earning a higher income and to replace them with an external supply of laborers from the agricultural labor market.

the hierarchical partitions with *k*-means partitions. Combining two partition methods can significantly improve the accuracy of clustering.

All variables are standardized by setting the maximum to 1 and minimum to 0, which is more consistent than standardizing to *z*-values (Milligan and Cooper 1988). Standardizing them forces relative values of each variable to have the same weight in cluster analysis. For example, suppose variable A is ranged from 0 to 10, while variable B is ranged from 0 to 1. Then, a difference in the value of A by 1 is considered to have the same importance as a difference in the value of B by 0.1. Although standardizing all variables is common practice in cluster analysis, its theoretical foundation is still rather loose and needs to be investigated in future studies.

Table 4.4 summarizes the key characteristics of the types of households.[8] First, the households are largely clustered into four groups: small farm households (lowland based), small farm households (upland based), extremely small farm households (with own farmland less than 0.1 hectare), and medium-to-large farm households (with own farmland greater than 2.5 hectares). As was discussed previously, the latter two groups differ from the first two groups. The extremely small farm households tend to grow more vegetables and are less likely to use tractors, while the medium-to-large farm households are more likely to both own and use tractors.

Based on the aforementioned cluster analysis method, we further classify the first two groups into eight types: (A) middle income, small subsistence; (B) cash crop growers; (C) fertilizer-based intensifiers; (D) power-intensive mechanizers; (E) traditional lowland producers; and (F) intensive labor hirers, all of which are lowland based; and (G) upland-based intensifiers as well as (H) traditional (upland-based) nonrice growers. Within the Terai in 2010, fertilizer-based intensifiers, power-intensive mechanizers, intensive labor hirers, and small farm households owning less than 0.1 hectare of land were the relative majority, each accounting for 15 to 22 percent of all farm households in the region (Table 4.5), indicating that significant shares of farm households follow different patterns of intensifying external, nonland input use.

Except middle-income small subsistence farmers, most farmers use their land extensively, with a cultivated area often more than twice as large as the owned area, indicating that they cultivate their own plots twice a year, plus rent in small plots of lands. Traditional farm households (both lowland based and upland based) use significantly less external inputs per hectare of owned land (valued at 149 and 196 kilograms of cereals per hectare) compared with other household types. Cropping patterns, as indicated by the revenue shares of major crops grown, do not vary widely across types, except for cash crop growers who specialize more in sugarcane and traditional upland growers who rely more on maize and vegetable production. Per capita expenditure and level of education are generally positively associated with the overall input use intensification. They are also generally negatively associated with elevation and terrain ruggedness,[9] with cash crop growers and large farm households found on the lowest land with the smoothest terrain.

The share of farm households using tractors is higher among cash crop growers (74 percent), power-intensive mechanizers (96 percent), intensive labor hirers (58 percent), and large farm households (82 percent), as well as fertilizer-based intensifiers (47 percent) and upland-based intensifiers (46 percent). It is much lower among small farm households and the remaining three types of farm households. Tractor use is substantially more intensive among power-intensive mechanizers, who pay on average an amount worth 269 kilograms per hectare of cereals. Given that the tractor rental price in the Terai in 2010 was around 45 kilograms of cereals per hour (calculated from Tables 2.10 and 2.15), this is equivalent to six hours of tractor use per hectare.

[8] We do not show the dendrogram because the cluster analysis here is a modified version, which combines hierarchical analysis with *k*-means analysis. Since the analysis is conducted not through a standard software package but rather through a manually coded program, there is no corresponding dendrogram and there are no other standard computer outputs.

[9] Elevation was calculated as the average within village development committees of the sample, based on GTOPO30 (USGS 1996). The terrain ruggedness index is calculated based on the formula developed by Riley, DeGloria, and Elliot (1999) and used in Nunn and Puga (2012).

Table 4.4 Characteristics of major types of farm households in the Terai owning 0.1 to 2.5 hectares of farmland

	Small farm households								Extremely small farm households	Medium-to-large farm households
	Lowland based						Upland based			
	A	B	C	D	E	F	G	H	I	J
Description	**Middle income, small subsistence**	**Cash crop (sugarcane) growers**	**Fertilizer-based intensifier**	**Power-intensive mechanizer**	**Traditional (lowland)**	**Intensive labor hirers**	**Upland-based intensifiers**	**Traditional (upland based), nonrice**	**Small (own farm < 0.1 ha)**	**Large (own farm ≥ 2.5 ha)**
Owned farm (ha)	0.5	0.9	0.6	0.5	0.5	0.8	0.5	0.5	0.03	4.4
Cultivated farm (ha)	0.5	1.8	1.3	1.3	1.1	1.7	1.5	1.0	0.6	7.2
External input cost (kg of cereals/ha)—mean	713	888	644	896	149	863	689	196	1355	896
External input cost (kg of cereals/ha)—median	363	722	485	662	144	716	410	171	422	770
Tractors	21	107	39	269	3	60	62	6	149	116
Fertilizer	114	284	348	251	25	173	234	45	339	206
Irrigation	171	151	142	144	109	129	165	122	298	161
Hired labor	21	275	58	134	3	449	138	14	230	349
Others	385	71	58	99	9	52	90	9	339	63
% of lowland in cultivated area	95	82	92	97	91	94	8	10	60	89
% revenue share										
Rice	41	10	50	55	44	53	42	11	36	50
Wheat	13	3	16	12	11	13	13	6	7	12
Maize	1	2	1	2	3	3	3	21	5	1
Lentils	5	3	5	4	4	5	5	3	3	5
Sugarcane	0	68	1	1	0	1	0	4	0	7
Vegetables	11	3	4	6	8	5	10	11	18	4

Table 4.4 Continued

	Small farm households								Extremely small farm households	Medium-to-large farm households
	Lowland based						Upland based			
	A	B	C	D	E	F	G	H	I	J
Description	**Middle income, small subsistence**	**Cash crop (sugarcane) growers**	**Fertilizer-based intensifier**	**Power-intensive mechanizer**	**Traditional (lowland)**	**Intensive labor hirers**	**Upland-based intensifiers**	**Traditional (upland based), nonrice**	**Small (own farm < 0.1 ha)**	**Large (own farm ≥ 2.5 ha)**
Key excluded variables										
% using own tractor	2	6	0	0	1	3	1	0	0	22
% using tractor	20	74	47	96	9	58	46	8	32	82
Per capita expenditure (measured worth kg of cereal)	3,114	4,190	2,481	2,912	2,489	3,739	2,526	2,160	2,428	5,821
Years of formal education (working-age members)	4.1	4.1	3.1	4.2	3.5	4.7	4.2	2.9	2.8	6.9
Elevation (mean)	187	117	212	186	229	165	249	422	227	142
Ruggedness	36	23	56	51	79	44	79	185	69	35

Source: Authors' estimation based on NLSS and modified cluster analysis.
Note: ha = hectare; kg = kilogram.

The composition of farm household types in Table 4.4 varies across the zones within the Terai (Table 4.5). The Eastern and Central regions have relatively higher shares of (F) intensive labor hirers, while the Western region has a high share of (D) power-intensive mechanizers. In the Midwestern and Far Western regions, (C) fertilizer-based intensifiers are commonly found (lowland-based traditional farmers are also common in the Far Western region). Since the cluster analysis was conducted for all samples from three rounds of the NLSS, transitions of composition over time are also observed as are presented in Table 4.6. Within the Terai, shares of (D) power-intensive mechanizers and (F) intensive labor hirers have increased from 1 percent and 15 percent in 1995 to 15 percent and 24 percent in 2010, respectively, while the share of (C) fertilizer-based intensifiers has stagnated and that of (I) small farmers increased first up to 2003 and decreased since then.

Tractor renters in the Terai in 2010 mostly fell under three types (Table 4.7): power-intensive mechanizers, who intensify input use by using tractors intensively per hectare of cultivated area (mostly found in the Western and Central regions); intensive labor hirers, who intensify input use by hiring many laborers and substitute for some of them with tractors (though tractor use is less intensive per hectare) (mostly found in the Eastern and Midwestern regions); and fertilizer-based intensifiers, who still rely mostly on fertilizer to intensify input use (mostly found in the Far Western region).

Because the composition of farm household types varies across regions within the Terai (Table 4.5), the composition of tractor renters in Table 4.7 also varies across regions (Table 4.8). Most tractor renters in the Eastern region are (F) intensive labor hirers, whereas in the Central region they are (D) power-intensive mechanizers and (F) intensive labor hirers and in the Western region (D) power-intensive mechanizers dominate. In the Midwestern and Far Western regions, they are fairly equally split across (C) fertilizer-based intensifiers, (D) power-intensive mechanizers, and (F) intensive labor hirers.

Table 4.5 Distribution of farm household types by region, the Terai, 2010 (%)

Region	Middle income, small subsistence	Cash crop (sugarcane) growers	Fertilizer-based intensifier	Power intensive-mechanizer	Traditional (lowland)	Intensive labor hirers	Upland-based intensifiers	Traditional (upland based), nonrice	Small (own farm < 0.1 ha)	Large (own farm ≥ 2.5 ha)
Terai	5	3	15	17	7	22	4	3	19	4
Eastern	3	1	7	11	7	34	3	1	27	5
Central	3	6	14	19	2	25	3	3	19	5
Western	4	3	24	38	4	8	3	2	9	4
Midwestern	10	0	23	5	9	14	10	12	15	2
Far Western	10	1	22	7	25	11	4	3	14	3

Source: Authors' estimation based on NLSS (Nepal, CBS year) and modified cluster analysis.
Note: Figures are adjusted for sample weights.

Table 4.6 Changes in farm household composition between 1995 and 2010, the Terai (%)

Year	Middle income, small subsistence	Cash crop (sugarcane) growers	Fertilizer-based intensifier	Power-intensive mechanizer	Traditional (lowland)	Intensive labor hirers	Upland-based intensifiers	Traditional (upland based), nonrice	Small (own farm < 0.1 ha)	Large (own farm ≥ 2.5 ha)
1995	6	2	20	1	13	15	3	5	24	11
2003	5	2	16	9	8	17	4	4	29	6
2010	7	3	15	15	6	24	4	4	19	4

Source: Authors' estimations based on NLSS (Nepal, CBS year) and modified cluster analysis.

Table 4.7 Types of tractor owners and tractor renters in the Terai, 2010

Tractor owners		Tractor renters	
Type	**%**	**Type**	**%**
Large farm (> 2.5 hectares [ha] of own farm)	51	Power-intensive mechanizer	32
Intensive labor hirers	28	Intensive labor hirers	25
Cash crop (sugarcane) growers	9	Fertilizer-based intensifier	15
Middle income, small subsistence	5	Small farm (< 0.1 ha of own farm)	13
Upland-based intensifiers	3	Large farm (> 2.5 ha of own farm)	5
Fertilizer-based intensifier	3	Cash crop (sugarcane) growers	4

Source: Authors' estimations based on NLSS (Nepal, CBS year) and modified cluster analysis.

Table 4.8 Types of tractor renters in the Terai by region, 2010 (%)

Region	Middle income, small subsistence	Cash crop (sugarcane) growers	Fertilizer-based intensifier	Power-intensive mechanizer	Traditional (lowland)	Intensive labor hirers	Upland-based intensifiers	Traditional (upland based), nonrice	Small (own farm < 0.1 ha)	Large (own farm ≥ 2.5 ha)
Eastern	1	1	4	25	1	44	3	0	11	8
Central	0	7	15	29	0	24	2	1	16	5
Western	4	4	19	51	0	7	3	0	8	2
Midwestern	2	0	22	18	5	24	13	2	11	5
Far Western	6	0	26	20	9	17	6	0	10	4

Source: Authors' estimations based on NLSS (Nepal, CBS year) and modified cluster analysis.

Implications of the Typological Analysis

A typology of this sort is important because different policy recommendations and hypotheses potentially apply to different types of farm households. Here we provide some examples of key hypotheses regarding appropriate policies that future research can further investigate.

Power-intensive mechanizers may use tractors intensively relative to other land and nonland inputs typically for power-intensive activities like plowing, possibly because land productivity improvement may depend highly on intensive, repeated plowing that is applied multiple times to plots. For power-intensive mechanizers, policies that reduce the cost of deep plowing through the development of more efficient plowing machines can substantially increase their incomes or lead to lower food prices.

Intensive labor hirers, for similar reasons, intensively hire laborers because productivity depends on labor-intensive production practices, including not only some plowing but also improved control-intensive planting practices such as transplanting or intensive weeding on large plots of land. They may differ from intensive mechanizers in that providing improved labor-intensive production management practices for various production activities is more important than concentrating on conducting intensive plowing at the beginning of the seasons. For intensive labor hirers, mechanization can be beneficial if diverse machinery is available that can mechanize varieties of production management activities, such as planters and weeders, which may not be as important for power-intensive mechanizers.

Fertilizer-based intensifiers may rely on intensive use of fertilizer, as improving their productivity may depend largely on improving soil fertility but not so much on labor-intensive practices or intensive use of power-intensive operations like plowing once the minimum plowing is done by tractors. For them, demand for mechanization may depend largely on fertilizer price and availability as well as soil fertility, but demand for intensive mechanization may be limited.

Traditional lowland farmers, another common type in the Terai, may face limited technological options that do not warrant intensive input use. Consequently, returns from mechanization may be low for them, and policies to induce general intensification are needed, through the development and introduction of improved varieties.

These hypotheses can be further investigated in the future. In particular, appropriate mechanization promotion policies—including potential voucher piloting systems and the appropriate mode of support for custom hiring services—may differ according to the type of farm household. The farm household types we have identified can provide an entry point for developing appropriate targeting mechanisms in future studies.

5. SUMMARY AND CONCLUSION

The Terai belt in Nepal has seen some of the fastest growth in tractor use in Asia in the past 20 years, without substantial farm size expansion. The Nepalese government recently formulated the Agricultural Mechanization Promotion Policy 2014, which aims in part to reduce food production costs through improving mechanization efficiency. While the Terai is relatively homogeneous within Nepal's diverse production environment, significant heterogeneity exists among farm households across regions. Thus we need to assess how the government can tailor mechanization policies to specific types of farmers. Using three rounds of the NLSS, this study provides insight into such heterogeneity from a farm typology perspective. In this section, we highlight the key patterns found, as well as important hypotheses that can be further investigated in future studies.

Total farmland as well as farm size distribution stayed relatively fixed between 2003 and 2010, although the land–labor ratio has begun to increase slightly. Land transactions have been relatively limited. Growing tractor use in the Terai does not seem to be inducing land consolidation. The associations between tractor ownership, rentals, and size of land owned and cultivated (Table 2.7) are more likely to be due to selective adoption of tractors by households who already own large farms (Figure 2.3), rather than tractor use inducing farm size expansion. Between 2003 and 2010, input use intensification (external inputs excluding family labor and potential land values) per cultivated area grew relatively more than average operational scale per capita. If land fragmentation is a constraint, incentivizing land consolidation and promoting cooperative or contract farming may partly address the constraints for tractor adoption, although policymakers must identify the conditions under which such cooperative and contract farming systems can be profitable and privately sustainable.

Intensification per unit of land has been a more common trend in the Terai in this period than farm size expansion. Tractor use in the Terai has grown as part of such land-saving intensification, although larger farm owners do hire in more tractors. Despite the small, atomistic farm types in the Terai, tractor use grew through custom hiring provided by a small number of specialized tractor owners, rather than through widespread ownership of smaller tractors. Tractor use growth in the region is consistent with the trend of wage increases relative to tractor rental prices. However, some laborers seem to have entered the agricultural labor market instead of remaining as family labor (which may be reflected in the growth of landless workers), seeking employment on larger farms/tractor-renting farms. Such growth in labor hiring may constitute an important parallel process to growing tractor adoption, particularly among intensive labor hirers. Spatial divisions of labor in both the agricultural and nonagricultural sectors had already begun to emerge by the early 2000s (Fafchamps and Shilpi 2003).

A fraction of farm households, cultivating less than 0.2 hectare of land, have converged as nonmechanized farm households (using neither tractors nor draft animals), specializing in vegetables, noncitrus fruits, or spices and renting out land, shifting away from rice production. In some regions, such households account for up to one-quarter of total farm households. Currently emerging mechanization services do not seem to be able to break into this level of scale, and research on possible mechanization options for these households may be warranted.

Tractor Renters

Tractor rental costs account for only a small share of total crop production costs of farm households. This pattern possibly reflects the generally small land size in Nepal's Terai. Tractor rental is growing along with intensification rather than extensification—it is growing alongside intensified uses of hired labor, fertilizer, and irrigation per unit of cultivated land. To be more precise, the tractor as well as other external inputs may be substituting for family labor. Switching from draft animals to tractor rentals may make sense only if overall input intensification becomes profitable (for example, with improved varieties, improved infrastructure, considerable cost advantages relative to the cost of draft animals and animal husbandry, among others). Cost savings from substituting for manual work may be insufficient to induce tractor use. Tractor rental is partly motivated by market-oriented production, but subsistence production

still dominates (intensified input use may be financed by growing remittances). Tractor rental may also be motivated by increased subsistence food consumption. Based on the typology, we identify three major types of tractor renter with some geographical associations (power-intensive mechanizer, intensive labor hirer, fertilizer-based intensifier). The presence of distinct types suggests that differential mechanization policy options can be more efficient.

Tractor Owners

Compared with tractor rentals, an association is clearer between tractor ownership and farm size; owning a tractor makes sense if 5 or more hectares of land can be cultivated per year, which practically requires owning 2.5 hectares or more (semiannual cultivation) as the land rental market in the Terai is still fairly limited in scope. Farmers typically invest in tractors primarily for the anticipated farming revenue increase, while remittances may play a limited role in this decision. For many, crop sales are the largest source of revenue. Also in terms of value, a majority of crop production is for sale. This is different from tractor renters, for whom a substantial expansion of crop production seems to be for increased subsistence food production.

By 2010, access to markets seems to have increasingly induced tractor ownership. Between 2003 and 2010, more tractor owners emerged in suburban areas or areas where access had improved (closer to various facilities than nonowners, unlike in 2003) (Table 3.2). This is in contrast to the trends prior to 2003, when tractor owners were often located in remote areas, compared with tractor renters. The use of tractors in peri-urban areas may differ from their use in rural areas, something future studies should investigate.

Characteristics of tractor owners have diverged; growth in ownership is led by the growth of both commercial farmers and higher-income nonfarm households interested in using tractors in a relatively limited extent. Owners of more expensive tractors earn much greater revenue from nonagricultural enterprises while also keeping to commercial farming, while owners of cheaper tractors specialize more in commercial crop production. Based on the typology of input intensification, we see three major types of tractor owner—large land owners, intensive labor hirers, and cash crop (sugarcane) growers. The first two are often large-scale commercial rice producers.

Other Key Patterns

Tractor rental growth in the Terai is only partly driven by cropping patterns: rice has remained dominant (80 percent of farm households specializing in rice or a rice-based production system) since 1995 despite changes in farm size, and increased tractor adoption has nevertheless happened despite relatively stable cropping patterns throughout this period. Changes in tractor adoption associated with cropping pattern changes seem relatively small. The only exceptions are the relatively more common tractor ownership among sugarcane growers and the particularly low tractor use among nonrice traditional upland farmers, as indicated in the typology.

The relative difference in wealth (income and expenditure) levels across mechanization status suggests important hypotheses. First, tractor owners are becoming increasingly distinctive types of households: in 2010, they typically enjoyed two to five times more per capita revenue and expenditures than tractor-renter farm households, and two to three times more than nonfarm households, with substantially larger asset holdings. The barriers to tractor ownership may remain substantially high, possibly due to the economies of scale enjoyed and the fixed investment required combined with credit constraints. This is consistent with the fact that a majority of tractor use has been enabled by hiring services. Whereas such division of labor can potentially lead to efficiency improvements in the agricultural sector (Zhang, Yang, and Reardon 2015), reliance on hiring services provided by large tractor owners can have trade-offs if the inefficiency due to this barrier is high (Takeshima 2015b). Such large disparity suggests a low social mobility (between tractor owners and others) potentially due to liquidity constraints, although more formal investigation is needed. This also suggests that the supply of tractor

hiring may still be constrained. How the recent growth in more scale-neutral machinery like power tillers and mini-tillers may lower these barriers warrants further investigation.

Second, tractor-renter farm households generally enjoy 30 to 50 percent higher per capita revenue, expenditures, and asset holdings than do farm households using only draft animals. While the causality needs further investigation, tractors (and the ability of tractor-hiring suppliers to serve a large number of small farmers) are allowing this type of farm household to prosper. Tractor renters, however, typically enjoy 20 to 25 percent less per capita revenue and expenditures compared with nonfarm households, although they enjoy significantly higher asset endowments. The motivation for farm households to exit farming and join nonfarm households may be strong. Therefore, the current mechanization landscape is somewhat dynamic and likely to continue evolving fast.

Lastly, we need more research to understand the considerably slower tractor adoption rates in the Hills and the Mountains. Tractor use has grown fast in the Terai, but slowly in other regions. Rising human capital and real farm wages are observed in the Hills and the Mountains. These factors appear to affect mechanization differently in the Hills and the Mountains compared with the Terai.

REFERENCES

Ahmed, R. 2001. *Recent Developments in Mechanized Cultivation: Emerging Issues in the Agriculture of Bangladesh*. February 2001. FMRSP Working Paper No. 33. Bangladesh Food Management & Research Support Project. Dhaka: Ministry of Food, Government of the People's Republic of Bangladesh. International Food Policy Research Institute.

Azogu, I. I. 2009. "Promoting Appropriate Mechanization Technologies for Improved Agricultural Productivity in Nigeria: The Role of the National Centre for Agricultural Mechanization." *Journal of Agricultural Engineering and Technology 17* (2): 1–10.

Barro, R., and J. W. Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950–2010." *Journal of Development Economics* 104: 184–198.

Berger, T., P. Schreinemachers, and J. Woelcke. 2006. "Multi-agent Simulation for the Targeting of Development Policies in Less-Favored Areas." *Agricultural Systems* 88: 28–43.

Byerlee, D., M. Collinson, R. Perrin, D. Winkelmann, S. Biggs, E. Moscardi, J. C. Martinez, L. Harrington, and A. Benjamin. 1980. *Planning Technologies Appropriate to Farmers—Concepts and Procedures.*Mexico City: Centro Internacional de Mejoramiento de Maiz y Trigo.

CSAM (Center for Sustainable Agricultural Mechanization). 2014. "Country Pages." Accessed July 2, 2014. http://un-csam.org/cp_index.htm.

Dorward, A. 2006. "Markets and Pro-poor Agricultural Growth: Insights from Livelihood and Informal Rural Economy Models in Malawi." *Agricultural Economics* 35 (2): 157–169.

Fafchamps, M., and F. Shilpi. 2003. "The Spatial Division of Labour in Nepal." *Journal of Development Studies 39* (6): 23–66.

FAO (Food and Agriculture Organization of the United Nations). 2014. FAOSTAT. Rome: FAO.

Houssou, N., X. Diao, and S. Kolavalli. 2014. *Economics of Tractor Ownership under Rainfed Agriculture with Applications in Ghana.* IFPRI Discussion Paper 01387. Washington, DC: International Food Policy Research Institute.

IRRI (International Rice Research Institute). 1986. *Small farm Equipment for Developing Countries.* Los Banos, the Philippines.

Johnson, M., H. Takeshima, and K. Gyimah-Brempong. 2013. *Assessing the Potential and Policy Alternatives for Achieving Rice Competitiveness and Growth in Nigeria*. IFPRI Discussion Paper 01301. Washington, DC: International Food Policy Research Institute.

Justice, S., and S. Biggs. 2013. "Rural and Agricultural Mechanization in Bangladesh and Nepal: Status, Processes, and Outcomes." In *Mechanization for Rural Development: A Review of Patterns and Progress from around the World*, edited by J. Kienzle, J. E. Ashburner, and B. G. Sims, 67-120. Rome: Food and Agriculture Organization of the United Nations.

Kienzle J., J. E. Ashburner, and B. G. Sims. 2013. *Mechanization for Rural Development: A Review of Patterns and Progress from around the World.* Rome: Food and Agriculture Organization of the United Nations.

Köbrich, C., T. Rehman, and M. Khan. 2003. "Typification of Farming Systems for Constructing Representative Farm Models: Two Illustrations of the Application of Multivariate Analyses in Chile and Pakistan." *Agricultural Systems* 76: 141–157.

Maystadt, J. F., V. Mueller, and A. Sebastian. 2014. *Environmental Migration and Labor Markets in Nepal.* IFPRI Discussion Paper 01364. Washington, DC: International Food Policy Research Institute.

Milligan, G. W., and M. C. Cooper. 1988. "A Study of Standardization of Variables in Cluster Analysis." *Journal of Classification* 5 (2): 181–204.

Nepal, CBS (Central Bureau of Statistics). 1996. *Nepal Living Standards Survey Report 1996: Main Findings.* Vol. 1. Computer disk. Washington, DC.

———. 2001. *Population and Housing Census 2001.* Computer disk. Washington, DC.

———. 2004. *Nepal Living Standards Survey II (2003/04): Survey Design and Implementation.* Computer disk. Washington, DC.

———. 2011a. *Nepal Living Standards Survey 2011/11: Statistical Report.* Vol. 1. Computer disk. Washington, DC.

———. 2011b. *Population and Housing Census 2011.* Computer disk. Washington, DC.

Nunn, N., and D. Puga. 2012. "Ruggedness: The Blessing of Bad Geography in Africa." *Review of Economics and Statistics* 94 (1): 20–36.

Pivovarova, M., and E. L. Swee. 2015. "Quantifying the Microeconomic Effects of War Using Panel Data: Evidence from Nepal." *World Development* 66: 308–321.

Punj, G., and D. W. Stewart. 1983. "Cluster Analysis in Marketing Research: Review and Suggestions for Application." *Journal of Marketing Research* 20 (2): 134–148.

Riley, S. J., S. D. DeGloria, and R. Elliot. 1999. "A Terrain Ruggedness Index That Quantifies Topographic Heterogeneity." *Intermountain Journal of Sciences* 5: 1–4, 23–27.

Roy, K. C., and G. Singh, 2008. "Agricultural Mechanization in Bangladesh." *Agricultural Mechanization in Asia, Africa and Latin America 39* (2): 83–93.

Siou, G. L., Y. Yasul, I. Csizmadi, S. McGregor, and P. J. Robson. 2011. "Exploring Statistical Approaches to Diminish Subjectivity of Cluster Analysis to Derive Dietary Patterns." *American Journal of Epidemiology* 173 (8): 956–967.

Takeshima H. 2015a. *Drivers of Growth in Agricultural Returns to Scale: The Hiring In of Tractor Services in the Terai of Nepal.* IFPRI Discussion Paper 01476. Washington, DC: International Food Policy Research Institute.

———. 2015b. *Market Imperfections for Tractor Service Provision in Nigeria: International Perspectives and Empirical Evidence.* IFPRI Discussion Paper 01424. Washington, DC: International Food Policy Research Institute.

———. 2016. "Understanding Irrigation System Diversity in Nigeria: A Modified Cluster-Analysis Approach." *Irrigation and Drainage*, forthcoming.

Takeshima, H., and H. Edeh. 2013. *Typology of Farm Households and Irrigation Systems: Some Evidence from Nigeria.* IFPRI Discussion Paper 01267. Washington, DC: International Food Policy Research Institute.

Takeshima, H., H. Edeh, A. Lawal, and M. Isiaka. 2015. "Tractor Owner Operators in Nigeria: Insights from a Small Survey in Kaduna and Nasarawa States." *Developing Economies* 53 (3): 188–217.

Takeshima, H., and L. Nagarajan. 2012. "Minor Millets in Tamil Nadu, India: Local Market Participation, On-Farm Diversity, and Farmer Welfare. *Environment and Development Economics* 17 (5): 603–632.

Takeshima H., A. Nin Pratt, and X. Diao. 2013. *Agricultural Mechanization Patterns in Nigeria: Insights from Farm Household Typology and Agricultural Household Model Simulation.* IFPRI Discussion Paper 01291. Washington, DC: International Food Policy Research Institute.

Ugwuishiwu, B. O., and A. P. Onwualu. 2009. Sustainability and Cost of Agricultural Mechanization in Nigeria as affected by Macro-Economic Policies. *Journal of Agricultural Engineering and Technology* 17 (2): 44-56.

USGS (US Geological Survey). 1996. GTOPO30. Sioux Falls, SD, US: USGS Center for Earth Resources Observation and Science.

Zhang, X., J. Yang, and T. Reardon. 2015. *Mechanization Outsourcing Clusters and Division of Labor in Chinese Agriculture.* IFPRI Discussion Paper 01415. Washington, DC: International Food Policy Research Institute.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

1487. *Public-private partnerships and the reduction of undernutrition in developing countries.* John Hoddinott, Stuart Gillespie, and Sivan Yosef, 2015.

1486. *How does women's time in reproductive work and agriculture affect maternal and child nutrition?: Evidence from Bangladesh, Cambodia, Ghana, Mozambique, and Nepal.* Hitomi Komatsu, Hazel Jean L. Malapit, and Sophie Theis, 2015.

1485. *US maize data reveals adaptation to heat and water stress*. Timothy S. Thomas, 2015.

1484. *Customary tenure and innovative measures of safeguarding land rights in Africa: The community land initiative (iniciativa de terras comunitárias) in Mozambique*. Hosaena Ghebru, Raul Pitoro, and Sileshi Woldeyohannes, 2015.

1483. *The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model description for version 3*. Sherman Robinson, Daniel Mason-D'Croz, Shahnila Islam, Timothy B. Sulser, Richard Robertson, Tingju Zhu, Arthur Gueneau, Gauthier Pitois, and Mark Rosegrant, 2015.

1482. *Enhancing food security in South Sudan: The role of public food stocks and cereal imports.* Paul A. Dorosh, Shahidur Rashid, Abigail Childs, and Joanna van Asselt, 2015.

1481. *Gender, headship, and the life cycle: Landownership in four Asian countries.* Kathryn Sproule, Caitlin Kieran, Agnes Quisumbing, and Cheryl Doss, 2015.

1480. *The food-energy-water security nexus: Definitions, policies, and methods in an application to Malawi and Mozambique.* Thea Nielsen, Franziska Schunemann, Emily McNulty, Manfred Zeller, Ephraim Nkonya, Edward Kato, Stefan Meyer, Weston Anderson, Tingju Zhu, Antonio Queface, and Lawrence Mapemba, 2015.

1479. *The making of public investments: Champions, coordination, and characteristics of nutrition interventions*, Tewodaj Mogues and Lucy Billings, 2015.

1478. *The dynamics of smallholder marketing behavior: Explorations using Ugandan and Mozambican panel data.* Bjorn Van Campenhout, 2015.

1477. *Adjusting to external shocks in small open economies: The case of Honduras.* Samuel Morley and Valeria Piñeiro, 2015.

1476. *Drivers of growth in agricultural returns to scale: The hiring in of tractor services in the Terai of Nepal.* Hiroyuki Takeshima, 2015.

1475. *The contribution of increased equity to the estimated social benefits from a transfer program: An illustration from PROGRESA.* Harold Alderman, Jere R. Behrman, and Afia Tasneem, 2015.

1474. *Reconstructing public expenditure data: Use of classification systems to better measure public spending in agriculture — A Mozambique case study*. Tewodaj Mogues, Leonardo Caceres, Francisco A. Fernandez, and Mariam B. Umarji, 2015.

1473. *Agricultural insurance and the World Trade Organization*. Joseph W. Glauber, 2015.

1472. *Grain price and volatility transmission from international to domestic markets in developing countries.* Francisco Ceballos, Manuel A. Hernandez, Nicholas Minot, and Miguel Robles, 2015.

1471. *Policy changes in times of crisis: Evidence from the Arab Spatial Policy Analyzer.* Jacopo Bordignon and Clemens Breisinger, 2015.

1470. *Gender empowerment gaps in agriculture and children's well-being in Bangladesh.* Hazel Jean L. Malapit, Esha Sraboni, Agnes R. Quisumbing, and Akhter Ahmed, 2015.

1469. *Climate change adaptation in agriculture: Ex ante analysis of promising and alternative crop technologies using DSSAT and IMPACT*. Sherman Robinson, Daniel Mason-D'Croz, Shahnila Islam, Nicola Cenacchi, Bernardo Creamer, Arthur Gueneau, Guy Hareau, Ulrich Kleinwechter, Khondoker Mottaleb, Swamikannu Nedumaran, Richard Robertson, Mark W. Rosegrant, Gbegbelegbe Sika, Timothy B. Sulser, Keith Wiebe, 2015.

1468. *A proximity-based measure of industrial clustering.* Jianqing Ruan and Xiaobo Zhang, 2015.

1467. *Aspirations and the role of social protection: Evidence from a natural disaster in rural Pakistan*. Katrina Kosec and Cecilia Hyunjung Mo, 2015.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org