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Adoption of zero-tillage wheat in the Eastern Indo-Gangetic Plains

Prospects for productivity growth and inclusive technology access

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IFPRI-TCI Workshop on Green Revolution in Eastern India

New Delhi, 09-10 Oct 2017

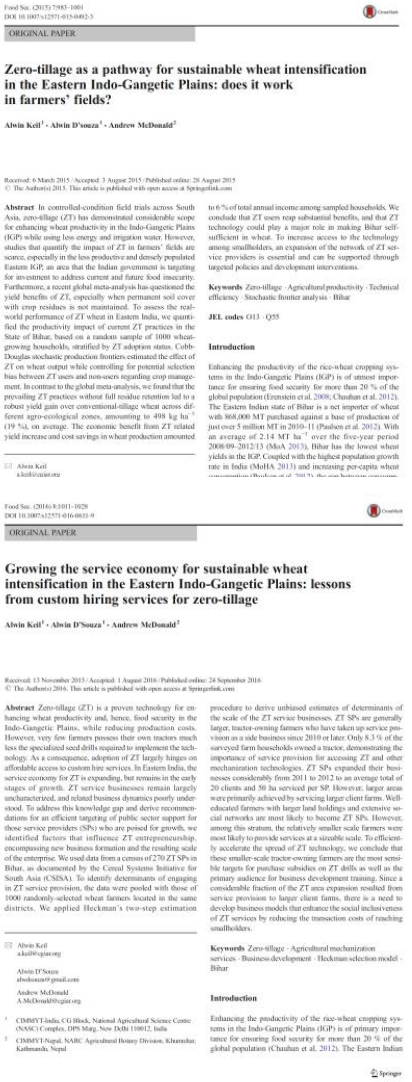
Zero-tillage wheat: background

- Bihar is a net-importer of wheat (Paulsen et al. 2012) and has the lowest wheat yields in the IGP, at 2.34 MT ha^{-1} over the period 2012/13 - 2013/14 (MoA 2015)

- Zero tillage (ZT) with residue retention in wheat has demonstrated considerable cost savings and yield benefits, while improving soil quality (Mehla et al. 2000; Erenstein and Laxmi 2008; Chauhan et al. 2012; Gathala et al. 2013; Krishna and Veettil 2014; Keil et al. 2015)
- ZT facilitates earlier wheat sowing, reducing risk of terminal heat stress

Performance of and access to ZT

- Surveys of farm households (N = 1,000) and ZT service providers (N = 245) conducted in Bihar in 2013.
- **Superior performance of ZT wheat** vs. conventional-tillage wheat is confirmed in farmers' fields: yield gain 498 kg/ha; economic gain 7,300 INR/ha (Keil et al. 2015).
- Only 8.3% of sample households own a tractor → **access to ZT technology depends on service providers (SPs)**.
- **Large and well-educated farmers with extensive social networks** are most likely to engage in ZT service provision; but, among those, the **smaller farmers** are most likely to **provide services at a large scale** (Keil et al., 2016).
- **Larger-scale SPs are more likely to stay in business** under less favorable subsidy conditions (economies of scale).



Food Sec. (2015) 7:983–1001
DOI 10.1007/s12571-015-0492-3

ORIGINAL PAPER

Zero-tillage as a pathway for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: does it work in farmers' fields?

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Received: 6 March 2015 / Accepted: 3 August 2015 / Published online: 28 August 2015
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Abstract In controlled-condition field trials across South Asia, zero-tillage (ZT) has demonstrated considerable scope for enhancing wheat productivity in the Indo-Gangetic Plains (IGP) while using less energy and irrigation water. However, studies that quantify the impact of ZT in farmers' fields are scarce, especially in the less productive and densely populated Eastern IGP, an area that the Indian government is targeting for investment to address current and future food insecurity. Furthermore, a recent global meta-analysis has questioned the yield benefits of ZT, especially when permanent soil cover with crop residues is not maintained. To assess the real-world performance of ZT wheat in Eastern India, we quantified the productivity impact of current ZT practices in the State of Bihar, based on a random sample of 1000 wheat-growing households, stratified by ZT adoption status. Cobb-Douglas stochastic production frontiers estimated the effect of ZT on wheat output while controlling for potential selection bias between ZT users and non-users regarding crop management. In contrast to the global meta-analysis, we found that the prevailing ZT practices without full residue retention led to a robust yield gain over conventional-tillage wheat across different agro-ecological zones, amounting to 498 kg ha^{-1} (19 %), on average. The economic benefit from ZT related yield increase and cost savings in wheat production amounted to 6 % of total annual income among sampled households. We conclude that ZT users reap substantial benefits, and that ZT technology could play a major role in making Bihar self-sufficient in wheat. To increase access to the technology among smallholders, an expansion of the network of ZT service providers is essential and can be supported through targeted policies and development interventions.

Keywords Zero-tillage · Agricultural productivity · Technical efficiency · Stochastic frontier analysis · Bihar

JEL codes O13 · Q55

Introduction

Enhancing the productivity of the rice-wheat cropping systems in the Indo-Gangetic Plains (IGP) is of utmost importance for ensuring food security for more than 20 % of the global population (Erenstein et al. 2008; Chauhan et al. 2012). The Eastern Indian state of Bihar is a net importer of wheat with 868,000 MT purchased against a base of production of just over 5 million MT in 2010–11 (Paulsen et al. 2012). With an average of 2.14 MT ha^{-1} over the five-year period 2008/09–2012/13 (MoA 2013), Bihar has the lowest wheat yields in the IGP. Coupled with the highest population growth rate in India (MoHA 2013) and increasing per-capita wheat

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Food Sec. (2016) 8:1011–1029
DOI 10.1007/s12571-016-0631-9

ORIGINAL PAPER

Growing the service economy for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: lessons from custom hiring services for zero-tillage

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Received: 13 November 2015 / Accepted: 1 August 2016 / Published online: 24 September 2016
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Abstract Zero-tillage (ZT) is a proven technology for enhancing wheat productivity and, hence, food security in the Indo-Gangetic Plains, while reducing production costs. However, very few farmers possess their own tractors much less the specialized seed drills required to implement the technology. As a consequence, adoption of ZT largely hinges on affordable access to custom hire services. In Eastern India, the service economy for ZT is expanding, but remains in the early stages of growth. ZT service businesses remain largely uncharacterized, and related business dynamics poorly understood. To address this knowledge gap and derive recommendations for an efficient targeting of public sector support for these service providers (SPs) who are poised for growth, we identified factors that influence ZT entrepreneurship, encompassing new business formation and the resulting scale of the enterprise. We used data from a census of 270 ZT SPs in Bihar, as documented by the Cereal Systems Initiative for South Asia (CSISA). To identify determinants of engaging in ZT service provision, the data were pooled with those of 1000 randomly-selected wheat farmers located in the same districts. We applied Heckman's two-step estimation procedure to derive unbiased estimates of determinants of the scale of the ZT service businesses. ZT SPs are generally larger, tractor-owning farmers who have taken up service provision as a side business since 2010 or later. Only 8.3 % of the surveyed farm households owned a tractor, demonstrating the importance of service provision for accessing ZT and other mechanization technologies. ZT SPs expanded their businesses considerably from 2011 to 2012 to an average total of 20 clients and 50 ha serviced per SP. However, larger areas were primarily achieved by servicing larger client farms. Well-educated farmers with larger land holdings and extensive social networks are most likely to become ZT SPs. However, among this stratum, the relatively smaller scale farmers were most likely to provide services at a sizeable scale. To efficiently accelerate the spread of ZT technology, we conclude that these smaller-scale tractor-owning farmers are the most sensible targets for purchase subsidies on ZT drills as well as the primary audience for business development training. Since a considerable fraction of the ZT area expansion resulted from service provision to larger client farms, there is a need to develop business models that enhance the social inclusiveness of ZT services by reducing the transaction costs of reaching smallholders.

Keywords Zero-tillage · Agricultural mechanization services · Business development · Heckman selection model · Bihar

Introduction

Enhancing the productivity of the rice-wheat cropping systems in the Indo-Gangetic Plains (IGP) is of primary importance for ensuring food security for more than 20 % of the global population (Chauhan et al. 2012). The Eastern Indian

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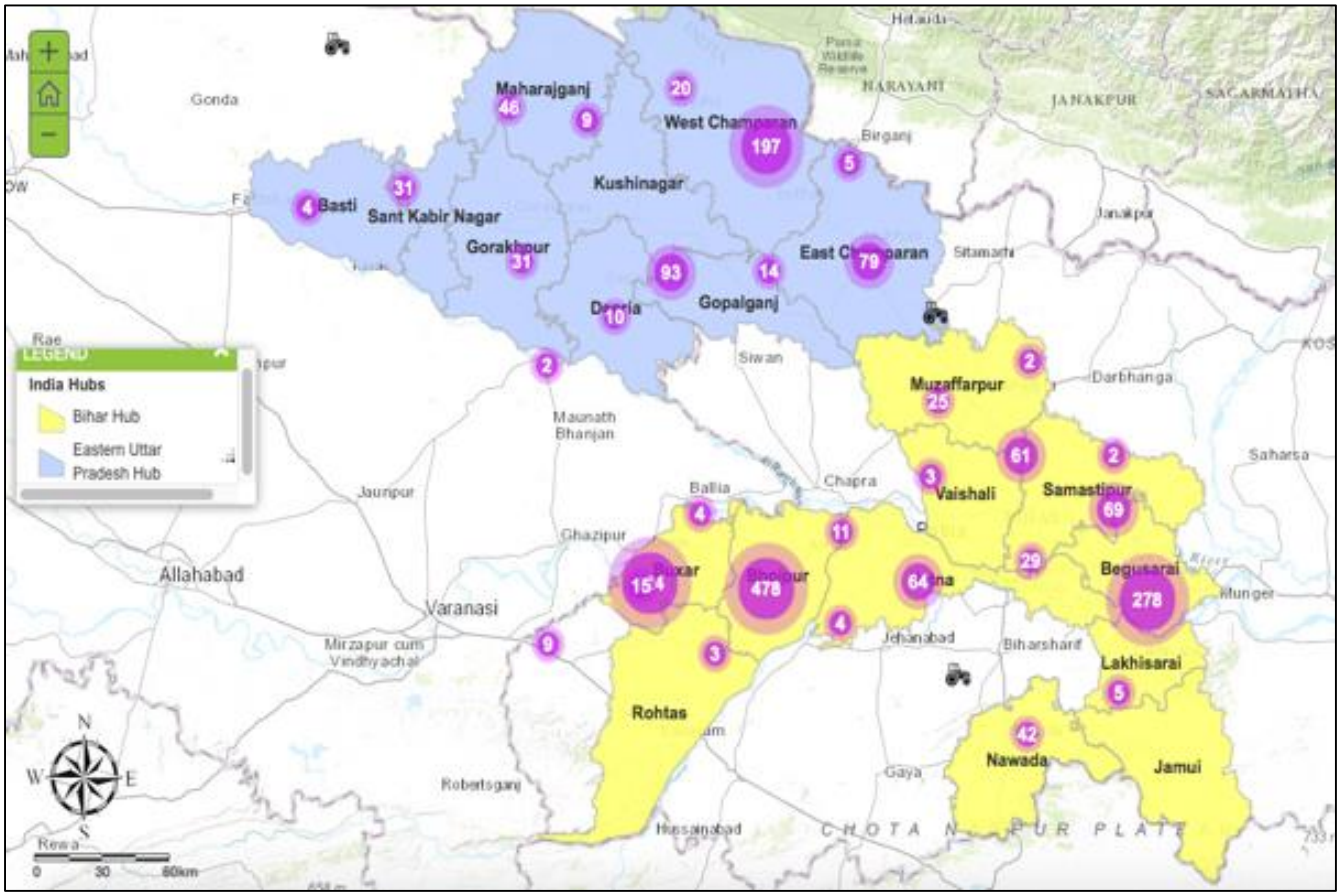
ZT service provision dynamics



No. ZT SPs in Bihar/EUP in

2012: 733

2013: 1,271

2014: 1,624

2015: 2,168

2016: 2,909

ZT service provision dynamics

- 229 out of 245 SPs surveyed in 2013 were revisited in 2016 (attrition 6.5%).
- **85% of SPs active in 2012 still provided ZT services in 2015.**
- SPs who dropped out had significantly fewer clients than those who continued.

Table 1. Development of number of customers per zero-tillage service provider from 2013 to 2015, differentiated by survey district (values are means, values in parentheses are medians)

	(1) Average no. customers 2013 - 15	(2) No. customers 2013	(3) No. customers 2014	(4) No. customers 2015	(5) Growth 2013-15 mean (%)	(6) Growth 2013-15 median (%)
Vaishali (N = 6)	20.7 (16)	21.0 (16)	20.7 (15.5)	20.5 (16)	-2.4	0.0
Begusarai (N = 33)	25.1 (20)	21.2 (17)	22.9 (20)	31.1 (22)	46.6	29.4
Samastipur (N = 24)	42.6 (35)	31.7 (26.5)	42.3 (35)	53.9 (47.5)	70.3	79.3
Bhojpur (N = 60)	31.6 (24.5)	29.0 (22.5)	32.4 (22)	33.5 (25)	15.5	11.1
Buxar (N = 26)	22.6 (15)	22.3 (16.5)	23.0 (15)	22.4 (15)	0.5	-9.1
Lakhisarai (N = 45)	32.7 (25)	28.6 (22)	32.1 (25)	37.4 (30)	30.8	36.4
Overall (N = 193)	**30.6 (22)**	**26.8 (20)**	**30.4 (24)**	**34.7 (25)**	**29.4**	**25.0**

Determinants of ZT adoption

(Keil et al., 2017)

- In 2013, only 45% of sample households knew about ZT.
- Clear **scale bias in awareness and use of ZT**.
- Fellow farmers are most important info source → account for **role of social networks in the adoption process**.
- Social networks are formed among **farmers of similar socioeconomic status**.
- Network effects particularly important among the smallest-scale farmers → **target extension messages at farmers representing different social strata**.
- **Proximate ZT service provider (< 5 km)** is important prerequisite to ZT use → continue to work on increasing number of SPs, especially in districts still poorly covered.
- **Time-saving potential of ZT** valued by farmers, especially under increasingly unreliable monsoon rains → **highlight risk mitigation aspect of ZT**.

ZT use dynamics

- 961 out of 1000 HHs surveyed in 2013 were revisited in 2016 (attrition 3.9%).
- Overall, **ZT use has increased by 32% over past 3 years, but dynamics vary across locations**.
- **13% of ZT testers have discontinued** the practice; main reason was lacking access to ZT services, followed by problems with weed infestation.
- In 2015/16 there was **still a significant scale bias** in awareness and use of ZT.
- Increase in ZT use has been more than proportionate among marginal farmers (< 1 ha) → **scale bias is decreasing**.

ZT use dynamics

Table 2. Basic farm characteristics, ZT related knowledge exposure, and use of ZT among sample households (HHs) in the 2012/13 and 2015/16 *rabi* seasons, differentiated by farm size terciles

					2012/13		2015/16		
Farm size tercile	(1) Mean cultivable area (ha)[1]	(2) Mean size of largest irrigable plot (ha)[1]	(3) % HH heads with education <5th grade[2]	(4) % HH heads belonging to Scheduled castes[2]	(5a) % HHs knowing how ZT works[2]	(6a) % HHs using ZT[2]	(5b) % HHs knowing how ZT works[2]	(6b) % HHs using ZT[2]	(7) Increase in use rate (%)
Smallest (N = 324)	0.28[a]	0.20[a]	42.42	22.73	27.2	19.1	67.0	29.6	55.0
Middle (N = 313)	0.89[b]	0.47[b]	29.59	10.06	42.0	28.3	77.0	38.3	35.3
Largest (N = 318)	2.70[c]	1.21[c]	19.57	4.35	65.3	43.3	91.8	52.2	20.6
Stat. sig.	***	***	***	***	***	***	***	***	
Whole sample (N = 955)	**1.28**	**0.62**	**30.61**	**12.42**	**44.9**	**30.3**	**78.5**	**40.0**	**32.0**

*(**)[***] Statistically significant at the 5% (1%) [0.1%] level of alpha error probability.

[1] Based on multiple Mann-Whitney tests, accounting for family-wise error.

[2] Based on Chi-square test.

Implications for CSISA

- **Overall increase in use of ZT** is encouraging.
- **Scale bias still significant, but gap is narrowing;** gap may be further narrowed through **extension messaging targeted at small-scale farmers** (more efficient use of social networks for within-village diffusion).
- Emphasize **risk-reducing aspect of ZT** (facilitates earlier wheat sowing).
- **Increase number of ZT SPs in districts still poorly covered**.
- Ensure that **weed control** is adequately addressed in technical training of SPs and awareness raising activities for farmers.
- Add **business development training** with **improved targeting** to SPs who are poised for growth to boost and sustain ZT related service economy.
- **Mainstream ZT into NARES partners' programming.**

ZT diffusion scenarios

- **Constant growth scenario:** ZT SPs 35% p.a.; Customers per SP 10% p.a.
- **Variable growth scenario:** ZT SPs 50% p.a. in years 1 – 3, 30% p.a. in years 4 – 5, then 20% p.a.; Customers per SP 5% p.a., 5% p.a., and 10% p.a., respectively.

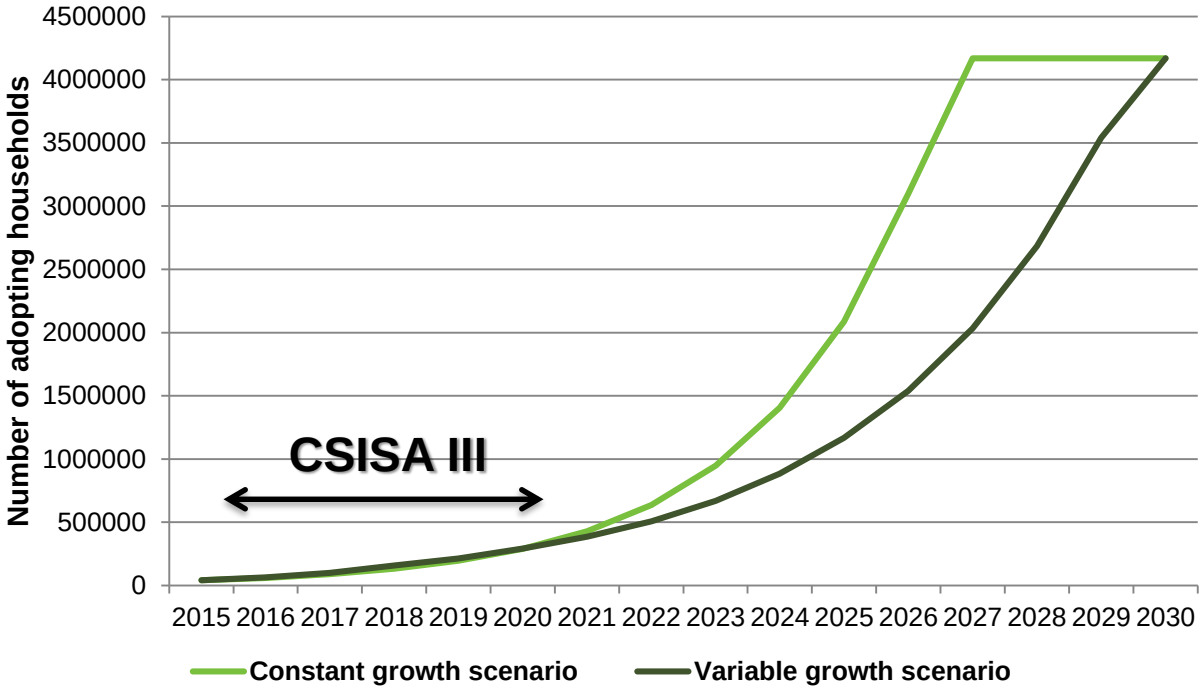
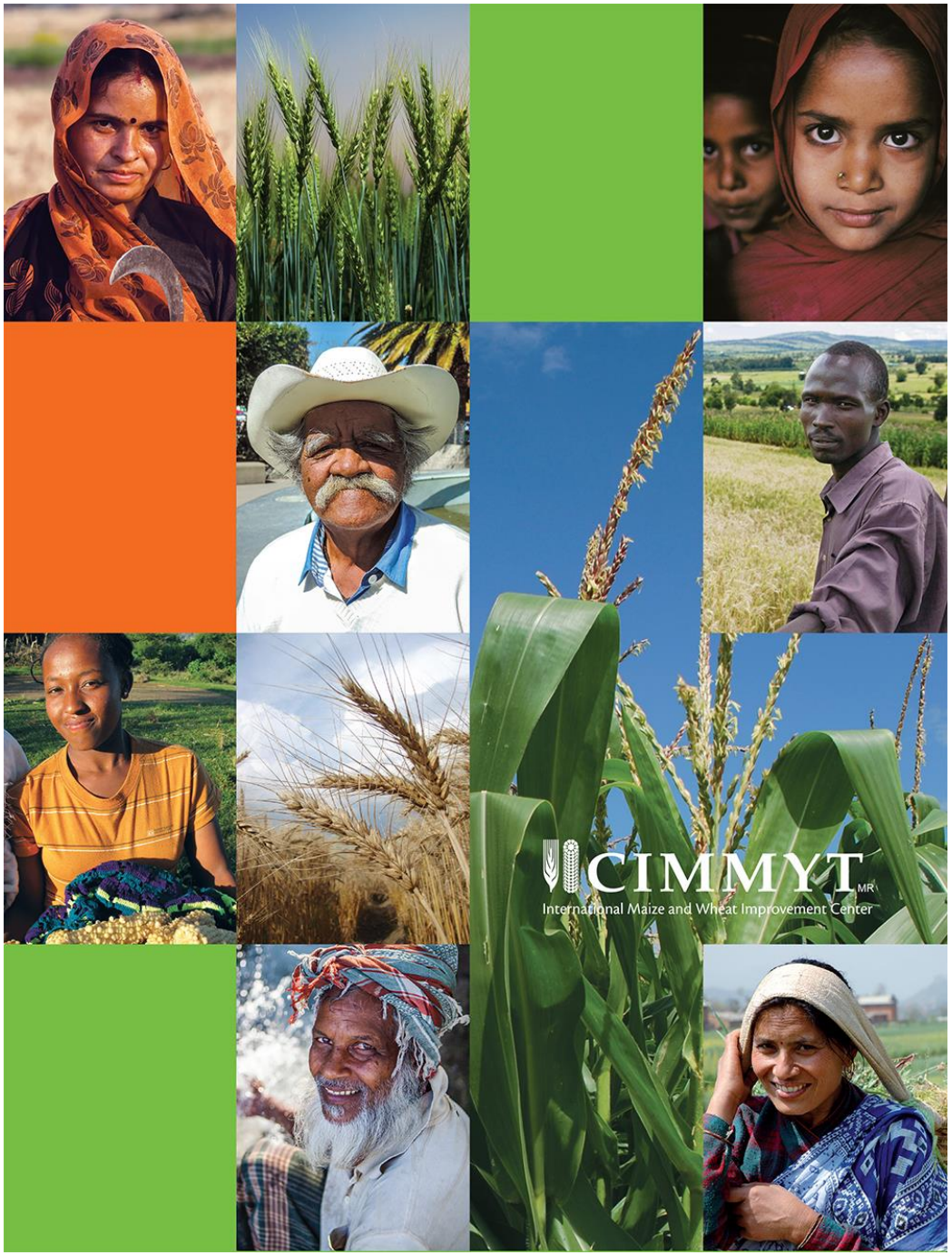


Figure 1. Projected diffusion of zero-tillage wheat within and beyond CSISA Phase III, based on different growth scenarios

Mainstreaming ZT scaling

- **Promote the concept of ZT & related service provision** → district- and state-level consultations with DoA, SAUs and others to foster favorable policy environment.
- **Enhance availability of ZT drills** → interactions with ZT drill manufacturers → target: increase number of ZT SPs by 35% per year.
- **Build ZT service provision capacity** → transition from direct training to training of trainers (ToT); expand training portfolio to include business development training; major strategic entry point for ToT activities are district-level *Krishi Vigyan Kendra*s (KVKs).
- **Sustain the business model of ZT SPs** → support emergence of network for spares and repairs; encourage business portfolio expansion into other mechanization services.
- **Enhance efficiency of policy support through better targeting** → e.g. target purchase subsidies for ZT drills to those SPs who are poised for growth.



Thank you for your interest!

References

Chauhan, B. S., Mahajan, G., Sardana, V., Timsina, J., Jat, M. L., 2012. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. *Advances in Agronomy* 117, 315-369.

Erenstein, O., Laxmi, V., 2008. Zero-tillage impacts in India's rice-wheat systems: A review. *Soil and Tillage Research* 100 (1-2), 1-14.

Gathala, M. K., Kumar, V., Sharma, P. C., Saharawat, Y. S., Jat, H. S., Singh, M., Kumar, A., Jat, M. L., Humphreys, E., Sharma, D. K., Sharma, S., Ladha, J. K., 2013. Optimizing intensive cereal-based systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. *Agriculture, Ecosystems and Environment* 177, 85-97.

Keil, A., D'Souza, A., McDonald, A. (2017) Zero-tillage is a proven technology for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: what determines farmer awareness and adoption? *Food Security* 9 (4), 723-743. https://link.springer.com/article/10.1007/s12571-017-0707-x

Keil, A., D'Souza, A., McDonald, A. (2016) Growing the service economy for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: lessons from custom hiring services for zero-tillage. *Food Security* 8 (5), 1011-1028. http://link.springer.com/article/10.1007/s12571-016-0611-9

Keil, A., D'Souza, A., McDonald, A. (2015) Zero-tillage as a pathway for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: does it work in farmers' fields? *Food Security* 7 (5), 983-1001. http://link.springer.com/article/10.1007/s12571-015-0492-3

Krishna, V. V., Veettil, P. C., 2014. Productivity and efficiency impacts of conservation tillage in northwest Indo-Gangetic Plains. *Agricultural Systems* 127, 126-138.

Mehla, R. S., Verma, J. K., Gupta, R. K., Hobbs, P. R., 2000. Stagnation in the productivity of wheat in the Indo-Gangetic Plains: Zero-Till-Seed-Cum-Fertilizer Drill as an integrated solution. RWC, New Delhi, India.

MoA, 2015. Agricultural Statistics at a Glance 2015. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Paulsen, J., Bergh, K., Chew, A., Gugerty, M. K., Anderson, C. L., 2012. Wheat value chain: Bihar. Evans School Policy Analysis and Research (EPAR) Brief No. 202. Evans School of Public Affairs, University of Washington, Seattle.