Final Report

Enhancing Rice Productivity and Food Security: A Study of the Adoption of the System of Rice Intensification (SRI) in Selected States of India

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Executive Summary

Rice is the most important staple food, consumed by half of the world's population every day. Around 90% of the rice produced is consumed in the Asian region. Therefore, rice security—ensuring enough rice for everyone—is equivalent to food security. Within the Asian region, India occupies a vital position as a major producer and consumer. However, rice cultivation in India in recent times suffers from several interrelated problems such as stagnation in productivity and concomitant environmental problems due to salinisation and waterlogging of fields. Since virtually all suitable land is already under cultivation, raising productivity seems to be the only way of ensuring food security.

System of Rice Intensification (SRI), which originated in Madagascar, is widely recognized as a promising systemic approach to enhance rice production by simultaneously reducing negative environmental externalities. By requiring less of the inputs, SRI is introduced through change in the management of plants, soil, water and nutrients. Since SRI is a knowledge-based innovation, it does not require any costly investment. Therefore, one would naturally expect SRI to be widely disseminated and adopted. But in reality this is not the case. Despite the potential benefits of SRI, its adoption rate is very low and also varies from region to region. Existing studies point out factors such as poor water control, lack of awareness, skill-intensive nature of the method, difficulty in getting labourers etc., as constraints in adoption. These could be the reasons for the common practice of partial adoption of components observed in most of the regions that adopted SRI. These constraints are even more severe in a developing country like India. Against this backdrop, the present study analysed the factors influencing the adoption of SRI as well as the impact of SRI adoption on household income and yield. The analysis is undertaken under three dimensions. First was the analysis of the factors that influence the intensity and depth of adoption by explicitly considering constraints which are relevant to SRI. Second was the analysis of the factors that influence the adoption of various components of SRI and the combinations of various

components of SRI. Third was the analysis of the adoption and impact of SRI on income and yield in a joint framework.

While the first two chapters were devoted to introduction, study area, data collection and socio-economic profile of the households, the third chapter made an analysis of the determinants of the intensity as well as the depth of adoption of SRI in India. The intensity is defined in terms of the number of acres devoted for the cultivation of SRI, whereas the depth is defined as the number of SRI components adopted. In a developing country, it is quite possible that markets function in an imperfect manner. Therefore, any technology adoption can be plagued by multiple constraints. Most of the earlier studies on technology adoption in agriculture assume that markets function perfectly and, therefore, agents do not face any information asymmetry. Although few recent studies have incorporated the multiple constraints in technology adoption in agriculture, there are hardly any such studies on SRI in general and for SRI in India in particular. Farmers who function in an imperfect market setting may lack information and access to seed, credit etc., which are crucial for adoption. Therefore, even a farmer with positive demand for adoption may not be able to adopt a new technology owing to several constraints. These could result in inconsistent parameter estimates. Therefore, the present study developed a multi hurdle model which is a modified double hurdle model.

The descriptive analysis showed that out of 386 household interviewed, only 38 farmers did not have any information regarding SRI. This constitutes only 10 per cent. The results, therefore, provide us with some policy relevant insights. The main reason for non-adoption was not lack of information about SRI; rather, it could be due mainly to other constraints. Around 63 per cent of non-adopters did not have access to extension services, thus pointing to the importance of extension services in the dissemination and adoption of SRI. Unlike other agricultural technologies, SRI is not a technology or an improved variety of a seed; instead, it is a set of innovative ideas. Similarly, around 60 per cent of non-adopters faced difficulty in getting labourers and in irrigation. Difficulty in getting labourers was a problem even among adopters of SRI. As far as the irrigation is concerned, although SRI is supposed to be less irrigation intensive, the analysis showed that the type of land is very important for effective irrigation. Land selected for SRI should be well levelled and should not have the problem of waterlogging. Also, while irrigating the plot, water should spread evenly across the field. Additionally, farmers must have their own irrigation facility so that irrigation can be done whenever needed.

As observed during the field visits, and as also highlighted in the existing literature, the present study decided to explicitly consider the above-mentioned constraints in our model. The constraints that are also generally highlighted in the adoption literature are access to seed, access to credit etc. Nonetheless, in the context of our present study, we do not consider these as major constraints in the adoption of SRI. This is due to the fact that neither SRI is specific to any seed variety nor does it require costly investment.

The results from the multi hurdle analysis showed that younger and large farmers had greater access to information. Gender of the head of the household, education, membership in farmers' organisations etc., were crucial factors in getting access to extension services. Age of the head of the household, cultivation of only rice, farming as main occupation, access to off-farm activity etc., were found to be important in increasing the likelihood of access to labourers. The farmers with farming as main occupation and rice as main farming face relatively less difficulty in getting access to labourers indicating that social network and long-standing relationship with labourers play an important role. As far as the disparities among districts in terms of constraints were concerned, the disparities were the highest in the case of access to information and this was followed by extension services. This study, therefore, indicates the lacunae of information and extension services in wider dissemination and adoption of SRI practices.

The results from the final adoption decisions showed that the factors influencing the intensity of SRI adoption was slightly different from the factors influencing the depth of SRI adoption. Nonetheless, the common factors that influence both intensity and depth were assets owned and rented, number of improved rice varieties known, membership in input supply cooperatives, and the fear of poor yield. So, it is clear that financial capital such as initial wealth and social capital such as membership in farmers' organisations are very crucial in terms of their effect on the adoption of SRI. Wage rates for labourers were crucial in the depth of adoption of SRI. Wage rates of woman labourers were negatively related to adoption whereas wage rate for male labourers were positively related to adoption. This is perhaps due to the fact that the shift away from manual weeding to mechanical weeding creates more demand for male labourers. So, the skill-intensive nature of mechanical weeding leads to higher demand for male labourers and, thus, to higher wage. This indicates a gender-biased nature of technical change.

The fourth chapter analysed the probability and level of adoption of multiple packages of SRI. SRI is a package of components and partial adoption is commonplace. Therefore, it is important to understand why farmers adopt only some and not all modified practices. We used multivariate probit (MVP) and ordered probit models to jointly analyse the adoption of multiple packages and the number of SRI packages adopted while taking into account the interrelationship among them. Our approach extends the existing empirical studies by allowing for correlations across different packages of SRI. The results show that various economic, institutional and access-related factors shape farmers' adoption of SRI packages.

The adoption of agricultural technologies in developing countries is mostly dependent on farmers' economic ability to access new technologies. The present study found a significant and positive relationship between households' assets and adoption of SRI packages. In line with the results from multi hurdle model, the results from MVP and ordered probit model also showed that certain fixed social bias and gender disparities were affecting the adoption. Despite considerable disparities in wage rates between male and female labourers, the analysis showed that female wage rates reduced the likelihood of adoption of almost all packages. Interestingly, the male wage rate generally increased the likelihood of adoption. The results highlight the skill-intensive nature of SRI adoption and the gender implications of SRI adoption.

Information and extension services are also very important driving-forces in enhancing adoption of SRI. Our results showed the importance of extension services in influencing adoption decisions. The insignificant impact of NFSM (National Food Security Mission) districts dummy on SRI adoption is an eloquent testimony to the fact that the objective of increasing rice production by promoting SRI under the Government's food security mission was not yielding the desired results. Additionally, most farmers who had been in farming for several years were not attracted to new methods. Also, farmers who were remotely located from the main market had higher likelihood of adopting SRI. This indicates the possibility of cultivating commercial crops by those farmers who were located close to the market. Most farmers interviewed did not consider rice farming as a commercially-viable venture and instead reported that the production was mainly for self-consumption and sale in the local markets.

The study also revealed the importance of investment in such infrastructure as irrigation in promoting SRI. Although, SRI requires less water as compared to traditional method, farmers require their own irrigation facility for the purpose of proper water management which is an essential component of SRI.

The need for social capital and networks were also observed in our analysis. The membership in farmers' organisations such as input supply cooperatives increased the likelihood of SRI adoption. This implies that policy makers need to focus on establishing and strengthening local collective institutions. Local institutions can play a crucial role in providing farmers with timely information, inputs and technical assistance.

The fifth chapter analysed the determinants and impacts of the adoption of five mutually-exclusive combinations of SRI on yield and household income using a multinomial endogenous treatment effects model. As in most adoption studies in general and in SRI adoption studies in particular, we find that the decision to adopt is a function of household assets, irrigation facility, information about SRI, contact with extension services, fear of poor yield, cultivation of other crops etc. Household assets, irrigation, information, extension services etc., increased the likelihood of household adopting SRI, whereas fear of poor yield, cultivation of other crops etc., decreased the likelihood of adopting SRI.

The outcomes of SRI adoption on yield and household income showed that all the three principles of SRI and its various combinations-plant management, soil management and water management-enhanced the rice yield. The positive impact of SRI adoption on household income was observed only when farmers adopted all the principles of SRI.

The impact analysis also showed that there were considerable differences in the impact of adoption across different States. Even with a greater adoption of SRI in states like Orissa and Madhya Pradesh as compared to Karnataka, the welfare outcomes of adoption was relatively low. This highlights the inherent differences in development. Although, education level of the farm households plays a key role realising the full benefits of SRI, an enhancement of irrigation management practices also assumes significance.

Briefly put, the three set of analysis undertaken in the study did not show any conflicts; instead, they provided more or less similar insights into the factors affecting the adoption. Although, lack of information did not turn out to be a major cause for non-adoption, there were considerable disparities in level of information across different districts studied. Extension services were found to be crucial and the results were consistent in all the models. Both the social and the economic capital of the farmers were found to be very important. Infrastructure-related issues such as irrigation also played a dominant role. Farmers who were in farming for several years were found to be very sceptical of adopting SRI, and risk aversion also played a role. But the most important revelations were in terms of fixed social bias and gender disparity. Despite considerable disparities in wage rates across male and female labourers, the study in general observed that female wage rate reduced the likelihood of adoption whereas male wage rate, in most cases, increased the likelihood of adoption. As mentioned earlier, this is due to the fact that the shift away from manual weeding to mechanical weeding resulted in greater demand for male labourers. The government's interventions in promoting SRI through the national food security mission did not seem to have had any impact.

The impact of SRI in enhancing rice yield and household income were observed in the analysis. The wider adoption of SRI can contribute to promoting not only sustainable agricultural practices but also for greater food security provided the constraints that the farmers are facing are addressed with appropriate policy interventions.

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Chapter 1
Introduction

1.1 Introduction

Rice is the staple food for more than half of the world's population and plays a pivotal role in food security of many countries. It constitutes nearly 26 per cent in total cereal production and nearly 20 per cent in total cereals trade (FAOSTAT, 2014). As the second largest producer and consumer, India plays an important role in the global rice economy. However, rice cultivation in India in recent times has suffered from several interrelated problems. Increased yields achieved during the green revolution period through input-intensive methods of high water and fertiliser use in well-endowed regions are showing signs of stagnation and concomitant environmental problems due to salinisation and waterlogging of fields. Water resources are also limited and water for irrigation must contend with increasing industrial and urban needs. As a consequence of all these, rice farmers experienced a downturn in productivity growth (International Food Policy Research Institute, 2009). The average productivity of rice in India, at present, is 2.2 tons/ha, which is far below the global average of 2.7 tons/ha. The productivity of Indian rice is higher than that of Thailand and Pakistan but much lower than that of Japan, China, Vietnam and Indonesia. The downturn in productivity growth coupled with the increase in global food grain prices continues to threaten food security in many low-income countries. Between 2001 and 2007 global rice prices nearly doubled, primarily due to fall in supply caused by stagnation of yield (Gujja and Thiyagarajan, 2009). Since there is not much scope of increasing the area of rice cultivation, the additional production has to come from less land, less water and less of other inputs.

The System of Rice Intensification (SRI), which originated in Madagascar, is widely recognized as a promising systemic approach to rice production for small-scale producers. This was introduced to help Malagasy farmers who had few economic resources. The method was supposed to be environmental friendly and was believed to enhance yield and substantially reduce water and other input requirements (Stoop et al., 2002; Uphoff, 2002, 2003) by changing the management of plants, soil, water and nutrients (Satyanarayana et al., 2007). Although just a different method of cultivation, it is widely treated as a new technology. The method totally deviates from the traditional way of cultivating paddy. A review of the literature shows that several innovations are taking place within the conceptual and practical framework of SRI. One such example is that of extending methods devised for irrigated areas to unirrigated (rainfed) areas as well as to other crops. Farmers in the eastern state of Jharkhand began experiments with SRI methods for their rainfed finger millet crop in 2005 and this is now known as System of Finger Millet Intensification (SFMI) (Abraham et al., 2014). These features distinguish SRI from rest of the technological innovations. The technical components of SRI are typically summarised as a list of five or six key practices that consists of crop establishment, water management and weed control, combined with soil aeration and the use of organic fertiliser (Stoop et al., 2002; Uphoff, 2007).

However the adoption of SRI is not without constraints. Certain components of SRI such as intermittent irrigation, although perceived to be water saving, require proper crop management and irrigation availability (Dobermann, 2004). Also, the agro-ecological conditions and environments in which SRI is evaluated may not be widely adaptable to other regions (Dobermann, 2004). Perhaps this explains why farmers in several regions do not adopt all components of SRI (Ly et al., 2012). Nonetheless, studies show that yield realisation under full adoption of SRI is significantly higher than partial adoption (Palanisami et al., 2013).

1.2 SRI in India and Review of Previous Studies

SRI had a rather delayed start in India. The first experiments with SRI in India were conducted by organic farmers in Pondicherry in the year 2000 (Prasad, 2007). The water saving potential of SRI was an important trigger that attracted farmers from many southern States to this new method (Basu and Leeuwis, 2012). In response to the widely-perceived need to improve water efficiency, some of the management practices of SRI were adopted while others were adapted to the local conditions (Senthikumar et al., 2008). Thus in India, SRI slowly started becoming popular with farmers and about 1 million hectares of area are under SRI cultivation, making it 2.42% of total area under rice cultivation in the country (Gujja and Thiyagarajan, 2009). Field trials are being conducted in all the major rice-producing states of India like West Bengal, Punjab, Gujarat, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka etc., and there is increasing involvement of farmers, government institutions, research agencies, and funding agencies to work together for a large-scale adoption of SRI. Although reliable data on actual levels of adoption and its impact are not available for India, the information that is accessible has attracted the attention of policymakers and planners. There are considerable efforts to promote SRI in different States.

Out of 564 rice-growing districts in India, SRI is being practiced by the farmers in about 216 districts (ICRISAT, 2008). Meanwhile, SRI is regarded as a key means of boosting national rice production under the Government of India's National Food Security Mission (NFSM).[1]

The available information confirms that SRI has increased yield and reduced the use of water in select locations (Palanisami et al., 2013). Thus SRI provides higher yields in various agro ecosystems with fewer inputs such as water, seeds or fertilizer (Barah, 2009; Zhao et al., 2009). Paddy nursery is raised using 2-3 kilograms of seeds per acre as against the usual 30 kilograms. A study done by Vasishth (2014) using input-output model showed that the direct and indirect input requirements for rice cultivation are decreased when cultivation shifts from traditional to SRI. SRI principles focus on neglected potentials to raise yields by changing farmers' agronomic practices towards more efficient use of natural resources. A recent report on Odisha also shows that the grain yield was higher even though the cost of cultivation was 3.2% higher (SANDRP, 2014).

Although several studies have highlighted the high-yield and low-cost benefits of SRI the rate of adoption remains low (Reddy et al., 2005). Studies find SRI to be more labour intensive (Noltze et al., 2012). The poor rate of adoption and high non-adoption rates are attributed to the fact that SRI is labour intensive and requires skill of farming (Barrett et al., 2004; Palanisami et al., 2013). The major constraints in the adoption of SRI/modified SRI practices are a lack of skilled manpower available in time for planting operations, poor water control in the fields, and unsuitable soils. Aversion to risk by farmers has also been highlighted by some studies as a reason for poor adoption (Johnson and Vijayaraghavan, 2011).

The study done by Devi and Ponnarasi (2009) on the adoption behaviour in Cuddalore district of Tamil Nadu using logistic regression model showed that lack of skilled labourers, awareness, training on new technology, farm income, experience etc., were the determinants for adoption behaviour of farmers. Another study conducted in Balaghat district of Madhya Pradesh to evaluate the factors affecting adoption decision using multiple regression analysis showed that age, education, cropping intensity etc., had a positive and significant impact on adoption (Chobitkar et al., 2012). A macro-level study covering 13 major rice producing

[1] The National Food Security Mission (NFSM) was launched in 2007 as a centrally-sponsored scheme to enhance food security through targeted production of rice, wheat and pulses and coarse cereals. Various interventions for commercial crops have also been proposed.

States using multinomial logit model showed that the factors such as soil type, source of irrigation etc., were important factors influencing the level of adoption in all the four regions (Southern, West, East, Central, North-East) (Palanisami et al., 2013). A study on Bardhaman district in West Bengal using logit regression model also showed that education level, distance from the canal etc., were important factors in adopting SRI (Haldar et al., 2012).

Although there is considerable literature analysing the potential of SRI to enhance the yield, there is hardly any study analysing the factors influencing the depth and intensity of adoption of SRI at the micro level for India. Intensity measures the number of acres devoted for SRI cultivation whereas depth measures the number of components of SRI being adopted. The few available studies on adoption of SRI and factors influencing the adoption of SRI in India have treated adoption as a binary dependant variable. Nonetheless, adoption is not simply a yes/no decision. The farmers can either adopt the entire package or some of the components. The factors influencing the intensity of SRI adoption can also vary from the factors influencing the depth of adoption. Since adoption is constrained by several factors, non-adopters can be expected to adopt this new technology only when the constraints are removed. In an imperfect market setting, even a farmer with positive demand for adoption may not able to adopt a new technology owing to several initial constraints such as lack of access to information, access to seed etc. (Shiferaw et al., 2008; Shiferaw et al., 2015). The few studies that we reviewed above in the Indian context point out several constraints such as lack of information, extension services, labour, and irrigation facility in adoption of SRI. There have hardly been any studies on SRI adoption by explicitly considering the constraints in the adoption decision.

Adoption of technology, which is usually introduced as a package, goes through a long process in terms of full adoption. Farmers often choose only parts of a package or apply combination of practices (Smale, Heisey, & Leathers, 1995). The set of explanatory variables that influence the decision to adopt one component can also influence the decision to adopt another component (Teklewold et al., 2013). Therefore, adoption decision is inherently multivariate. Most studies on adoption make use of univariate modelling approach. But this approach may, however, lead to inconsistent parameter estimation especially when there is interdependence and simultaneity in adoption between packages (Dorfman, 1996; Teklewold et al., 2013).

Similarly, there are hardly any studies that rigorously analyse the impact of SRI on household income and yield in a joint framework of adoption and impact. The factors influencing the adoption can also have an impact on the outcome variables (yield and income) therefore one need to address the endogenity issues. The endogenity can be addressed by analysing the factors influencing the adoption and the outcome variables in a joint framework. The multinomial endogenous treatment effects technique developed will address the issue of endogenity. The more details of this methodology is discussed in chapter 5.

Therefore, the present study contributes to the SRI literature by identifying the factors that influence the decision to adopt SRI and its impact on household income and yield.

1.3 Major Objectives of the Study

1. To analyse the factors affecting the adoption of SRI among the selected districts of India.
   a) The study aims to analyse the role of multiple binding constraints such as information, extension services, availability of labourers and irrigation in conditioning the adoption of SRI, intensity (in terms of number of acres devoted for SRI) and the depth of SRI adoption (in terms of the number of packages) by rice farmers in selected districts of India.
   b) The study aims to analyse the factors influencing the adoption of multiple packages of SRI by rice farmers in selected districts of India.

2. To analyse the impact of SRI adoption on rice yield and the household income.

1.4 Methodology

The factors influencing the adoption of SRI (both in terms of intensity and depth) will be analysed using a multi hurdle model which is a modified version of double hurdle model proposed by Cragg (1971). The multi hurdle model will explicitly incorporate multiple binding constraints that farmers face while making adoption decisions. The methodology is discussed in detail in chapter 3.

The analysis of factors influencing the adoption of multiple packages of SRI is done using multivariate probit as well as ordered probit models. A detailed discussion of this methodology is in chapter 4.

Finally, the impact of adoption of SRI on household income and rice yield is analysed using a multinomial endogenous treatment effects model proposed by Deb and Trivedi (2006a,b). The detailed discussion of the methodology is given in chapter 5.

1.5 Scope of the Study

Micro studies on technology diffusion among farmers are very important from policy perspective. The heterogeneity of agro-climatic and socio-economic factors can act as a hindrance in applying the learning from one place to another. Micro studies can provide useful background information about the farmers who are currently using a technology and those who are not. Without basic descriptive information on these two categories of farmers, it is difficult to know how to formulate policies aimed at improving agricultural productivity.

The study is intended to shed light into the factors influencing the adoption, intensity as well as the depth of adoption by explicitly considering multiple constraints in adoption. The study also analyses the factors influencing the adoption of multiple components of SRI. This is important especially since partial adoption of SRI is very common. From a policy perspective, it is very pertinent to understand region-specific constraints affecting the adoption of a technology and its components along with other socio-economic characteristics of farm households. Non-adoption of a technology by a farmer does not always indicate lack of interest in the technology; rather it could be due to several constraints such as lack of information, credit, seed etc. Therefore, even with a positive demand for adoption, a farmer may not be able to adopt a technology. Such insights are very crucial from a developing country perspective.

The study will also shed light into whether some of the Government's policy interventions are effective and, if not, how to make them more effective. The selection of a NFSM district from each State is undertaken in order to meet this objective. Out of two districts selected from each State, one district has SRI promotion through NFSM.

Another dimension of the study is to analyse the impact of SRI on yield and household income. Any positive impact of an adoption of a technology should lead to further sharpening of the policies in a more targeted manner.

1.6 Chapter Scheme

This study is divided into 6 chapters. Chapter 1 as an introduction gives the background, objectives, methodology, and the scope of the study along with chapter scheme. Chapter 2 provides a brief overview of data collection, study area, sampling and socio-economic profile of the sample households. Chapter 3 analyses the factors that influence the adoption of SRI under multiple-binding constraints. Chapter 4 provides an in-depth understanding of factors that influence the adoption of multiple packages of SRI. Chapter 5 then analyses the impact of SRI adoption on household income and yield. Finally, concluding observations and policy implications are discussed in Chapter 6.

Chapter 2

Data Collection, Study Area and Socio-Economic Profile of the Households

2.1 Data Collection

This study is based on primary data collected through a comprehensive household survey in six districts of three major rice-producing Indian States in the year 2015. The farmers were selected through multi-stage sampling technique. First, all rice-farming households in the selected blocks/taluks of SRI districts were listed and stratified into SRI participants and non-participants. The total number of farm households interviewed was 386, of which 193 households were SRI adopters. Detailed discussion of the identification of study area and socio-economic profile of the sample households are given in the subsequent sections.

2.2 Study Area

The States for analysis were carefully selected, taking into account the objectives of the study. The purpose of study is to make a detailed analysis of factors (institutional, social, economic, agronomic, demographic, market, risk, etc.) that influence the adoption at different stages and the impact on household income and yield. As a first step, all the major rice-producing States are identified. There are around 13 major rice-producing States and macro-level studies have already been undertaken for these States (Palanisami et al., 2013). Thus our analysis is focused at the micro level. Given the importance of identifying States that have sufficient SRI cultivation, three States with the highest differences in yield and gross margin between traditional and SRI cultivation are selected based on the existing studies (Palanisami et al., 2013).

Then there is the criterion of NFSM and non-NFSM districts. In order to further divide SRI districts into NFSM and non-NFSM districts, the States that we identify should have NFSM districts where SRI is promoted within the NFSM.

The SRI first took root in India primarily in the southern states of Tamil Nadu and Andhra Pradesh (Glover, 2011). SRI diffused first to Tamil Nadu, followed by Andhra Pradesh, and diffusion studies showed that the acceptance and spread of SRI was rapid in these two States (Johnson and Vijayaragavan, 2011).

As far as the rice-producing south Indian States are concerned (Tamil Nadu, Karnataka, Andhra Pradesh and Kerala), Kerala has around 6 SRI districts but does not have any NFSM districts. The remaining three south Indian States have both SRI and SRI-NFSM districts. The yield differences and gross margin difference between traditional rice cultivation and SRI was one of the lowest in Tamil Nadu and highest in Karnataka (Palanisami et al., 2013). Therefore, out of the four south Indian States the study decided to select Karnataka for the purpose of analysis.

Among the major rice-producing States from the western region (Gujarat, Rajasthan and Maharashtra), there were no SRI districts which were linked to NFSM. Moreover, even the number of SRI districts was relatively less as compared to other regions.

As for the States from the eastern region (Orissa, Chhattisgarh, Uttar Pradesh and West Bengal) the yield difference and the gross margin difference was the highest in Orissa. In the case of Chhattisgarh the gross margin difference was very less (2%) even when the yield differences were relatively high (Palanisami et al., 2013). Due to the considerable gap in yield and gross margin between traditional and SRI cultivation in Orissa, the study makes use of the State for the purpose of analysis.

Madhya Pradesh, the only rice-producing State from the central region, had good number of SRI and SRI-NFSM districts. Also, the yield difference and the gross margin difference were high and even one of the highest among all the major rice-producing States.

The major rice producing State from the north-eastern region (Assam) didn’t have many SRI and SRI-NFSM districts. The yield difference and gross margin difference were also at a low level.

Accordingly, 3 States are identified for the purpose of analysis based on the objectives of the study as well as above criteria. They are Karnataka, Orissa and Madhya Pradesh. For the purpose of further identification of the districts, the study made use of three criteria, viz., agro-climatic zones, SRI districts and SRI-NFSM districts. Thus, 2 districts from each State that belong to the same agro-climatic zones were identified. Selection of the districts in each

State belonging to same agro-climatic zones was done after ensuring that one is with SRI practice and the other is with SRI incorporated under NFSM.

For Karnataka, Hassan (SRI-NFSM) and Chikmagalur (SRI) districts are identified. Similarly for Orissa, Keonjhar (SRI-NFSM) and Mayurbhanj (SRI) districts are identified. For Madhya Pradesh, Sidhi (SRI) and Shahdol (SRI-NFSM) districts are selected. After selection of districts, the blocks/ taluks were selected from each district. The selected blocks/ taluks from each district were: Alur, Hassan and Sakleshpur from Hassan; Chikmagalur from Chikmagalur; Sadar, Patna, and Harichandapur from Keonjhar; Karanjia and Jashipur from Mayurbhanj; Sidhi and Sihawal from Sidhi; and Gohapru and Sohajpur from Shahdol.

Table 2.1 Overview of Sample Section from the Study Area

State	District	SRI farmers	Non-SRI farmers	Total farmers
Karnataka	Chikmagalur	21	21	42
	Hassan	20	20	40
Madhya Pradesh	Shahdol	30	30	60
	Sidhi	32	32	64
Orissa	Keonjhar	49	49	98
	Mayurbhanj	41	41	82
Total	All	193	193	386

Source: Survey data

2.3 Socio-Economic Profile

Household survey was conducted in six districts drawn from three States. A random sample of SRI adopters and non-adopters from each district was selected. The total number of households interviewed was 386. The total sample consisted of equal number of adopters and non-adopters. Agriculture was the main occupation and livelihood strategy for most of the farm households in the study districts. Farming was the main occupation for around 80% of total households interviewed. The farmers with farming as main occupation were slightly higher among adopters than non-adopters of SRI indicating greater possibility of full-time farmers choosing adoption. Among the adopters, around 86% of farmers had farming as their main occupation, whereas among the non-adopters, around 74% had farming as their main occupation (see Table 2.2).

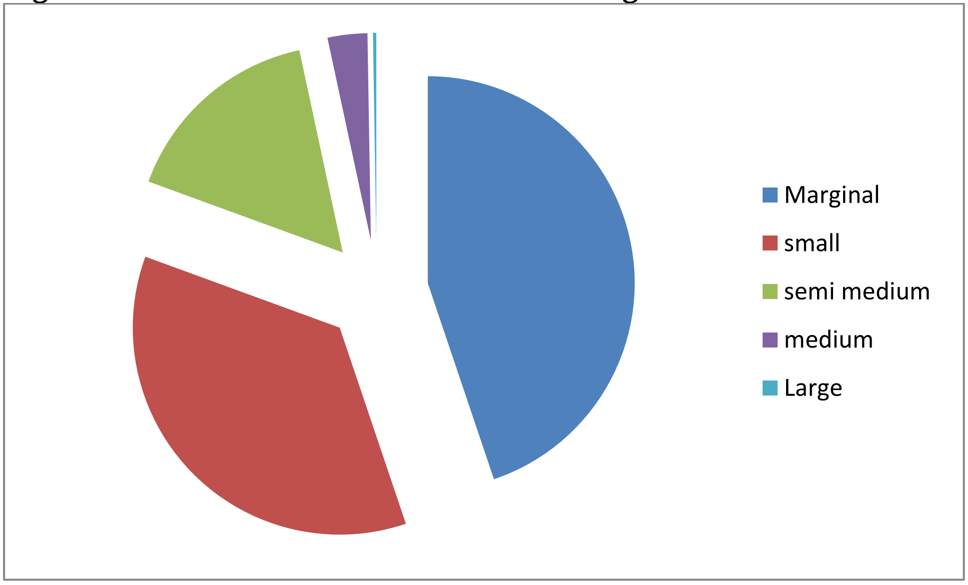
Majority of the farm households interviewed were either marginal farmers or small farmers. Marginal farmers were around 45%, small farmers around 36%, semi-medium farmers around 16%, medium farmers around 3% and large famers were less than 1% (see figure 2.1).

Table 2.2: Farming as Main Occupation

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
No	78	20.21	27	13.99	51	26.42
Yes	308	79.79	166	86.01	142	73.58
Total	386	100	193	100	193	100

Source: Survey data

Figure 2.1: Distribution of Farmers According to Farm Size



Source: Based on field survey data

Most farm households had male head of the households and the percentage share of male head of households among the total households was similar among both adopters and non-adopters (see Table 2.3).

Table 2.3: Gender of the Head of the Household

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
Female	37	9.59	19	9.84	18	9.33
Male	349	90.41	174	90.16	175	90.67
Total	386	100	193	100	193	100

Source: Survey data

The level of adoption of SRI was highest in 2 districts identified from Orissa and lowest in two districts identified from Karnataka. Paradoxically, even with wider adoption of SRI, the percentage of non-adopters who didn't have any information regarding SRI was the highest in Orissa (26%), followed by Madhya Pradesh (16%) and Karnataka (10%). Around 43% of the households opined that they were facing difficulty in terms of availability of labourers. The percentage of farmers who expressed difficulty in getting labourers was more or less the same among adopters and non-adopters indicating that availability of labourers was a major concern. Perhaps this could be a reason for lower level of adoption of SRI in Karnataka even with relatively better information about SRI. The percentage of non-adopters who expressed difficulty in getting labourers were one of the highest in Karnataka (56%) and lowest in Madhya Pradesh (34%). In Orissa, among the non-adopters, around 56% of the farmers expressed difficulty in obtaining labourers.

Out of total farmers interviewed, only 38 farmers didn't have any information regarding SRI. This constitutes only 10% of total sample and 20% of total non-adopters. The results indicate that lack of information may not be the main reason behind lack of adoption (see Table 2.4). Among the major sources of information regarding SRI, NGOs were the most proactive in terms of providing information about SRI to farmers. Around 40% of farmers received information about SRI from various NGOs. This was followed by agricultural department. Around 36% of farmers received information about SRI from government departments.

Table 2.4: Sources of Information

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
No information about SRI	38	9.84	0	0	38	19.69
Agricultural Department	139	36.01	90	46.63	48	24.87
NGO	155	40.16	96	49.74	59	30.57
Other	54	13.99	7	3.63	48	24.87
Total	386	100	193	100	193	100

Source: Survey data

If the lack of adoption is not primarily due to lack of information, then it must be due to other hindrances such as lack of extension services, training etc. The data shows that, out of total rice farmers, only around 47% of farmers had access to any sort of extension services (see

Table 2.4). The access to extension services was particularly limited among the non-adopters indicating that lack of extension services can be a reason for non-adoption. When around 57% of adopters had access to extension services, around 63% of non- adopters didn't have any access to extension services (see Table 2.5).

Table 2.5: Access to Extension Services

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
No Access	205	53.11	83	43.01	122	63.21
Have Access	181	46.89	110	56.99	71	36.79
Total	386	100	193	100	193	100

Source: Survey data

As far as the labour availability is concerned, around 43% of total farmers reported that they faced difficulty in getting labourers for rice cultivation, with the difficulty faced by non-adopters being slightly higher than adopters of SRI. Among the adopters only around 37% faced difficulty in getting labourers whereas among the non-adopters around 49% faced difficulty in getting labourers (see Table 2.6).

Table 2.6: Labour Availability

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
No difficulty	219	56.74	121	62.69	98	50.78
Have difficulty	167	43.26	72	37.31	95	49.22
Total	386	100	193	100	193	100

Source: Survey data

The data on source of irrigation for rice farmers shows that majority of the farm households relied solely on rainfall for irrigation. Around 50% of farmers had only rainfall as the main source for irrigation. After rainfall, the main source of irrigation was canal, followed by wells. Those who had bore well or sprinkler was only around 3%. The reliance on rainfall was higher among non-adopters than adopters. Among the adopters only around 40% relied upon rainfall whereas among the non-adopters around 60% had only rainfall as the main source. This indicates that the problem of lack of irrigation facility is a reason for non-adoption. After rainfall, canal and well remained the major sources for irrigation among both adopters as well as non-adopters (see Table 2.7).

Table 2.7: Source of Irrigation

Source of Irrigation	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
Rainfall	192	49.74	77	39.90	116	60.10
Pond	5	1.30	5	2.59	0	0.00
Well	54	13.99	38	19.69	15	7.77
Bore well/Sprinkler	13	3.37	10	5.18	3	1.55
Lake	2	0.52	1	0.52	1	0.52
River	38	9.84	20	10.36	18	9.33
Canal	82	21.24	42	21.76	40	20.73
Total	386	100	193	100	193	100

Source: Survey data

As far as the membership in farmers' organisations is concerned, around 60% of farmers did not have any membership with input supply cooperatives. The percentage of farmers who did not have any membership was higher among the non-adopters than adopters (see Table 2.8).

Table 2.8: Membership with Input Supply Cooperatives

	All		Adopters		Non-adopters	
	Nos.	%	Nos.	%	Nos.	%
No	232	60.10	100	51.81	132	68.39
Yes	154	39.90	93	48.19	61	31.61
Total	386	100	193	100	193	100

Source: Survey data

Majority of the farm households had farming not only as their main occupation but also as main source of income (see Table 2.9). Around 50% of total households, 55% of total adopters and 44% of non-adopters had farming as their main source of income. This was followed by wage labour. Around 33% of total households, 29% of total adopters and 36% of total non-adopters had wage labour as main source of income. Although the percentage share of farmers who had farming as the main source of income was less among the non-adopters than adopters, the percentage share of wage labour was relatively higher among non-adopters than adopters. This indicates that the lack of SRI adoption by non-adopters may not be due to availability of better opportunities but rather could be due to other factors such as lack of own cultivated land, higher rent for assets etc.

Table 2.9: Source of Income

	All		Adopters		Non-adopters	
Source of Income	Nos.	%	Nos.	%	Nos.	%
Farming	191	49.48	106	54.92	85	44.04
Service	1	0.26	0	0.00	1	0.52
Trading	2	0.52	0	0.00	2	1.04
Wage labour	3	0.78	0	0.00	3	1.55
Dairying/Poultry	7	1.81	0	0.00	7	3.63
Farming and service	21	5.44	12	6.22	9	4.66
Farming and wage labour	126	32.64	56	29.02	70	36.27
Farming and dairying	14	3.63	9	4.66	5	2.59
Farming and other	21	5.44	10	5.18	11	5.70
Total	386	100	193	100	193	100

Source: Survey data

2.4 Conclusion

The chapter discussed the rationale for choosing the study area, study sample, data and sampling technique adopted in the study along with sample households' socio-economic profile. The preliminary analysis of the data undertaken in this chapter revealed that majority of farm households were poor or marginal with farming or wage labour as their main sources of income. Additionally, majority of the households interviewed were headed by males. Interestingly, lack of information about SRI was not a major issue as only 10% of farmers lacked information regarding SRI. On the other hand, 53% of total farmers and 63% of non-adopters didn't have access to extension services clearly indicating that lack of training and guidance in terms of adoption were bigger concerns. Non-availability of labour was reported by most farmers, a major concern even among adopters of SRI. Similarly, 40% of adopters and 60% of non-adopters solely relied upon rainfall as the major source of irrigation indicating that lack of irrigation was a likely reason for non-adoption. This chapter identified the socio-economic profile of the farm households along with certain constraints such as lack of access to extension services, irrigation facility, availability of labour etc. The next chapter will deal with econometric estimation of the impact of several socio-economic factors on adoption decision by explicitly considering the multiple binding constraints in adoption.

Chapter 3
SRI Adoption under Multiple Constraints

3.1 Introduction

This chapter attempts to analyse factors influencing the intensity (in terms of acres devoted for SRI) and the depth (in terms of number of SRI components adopted) of adoption of SRI by explicitly considering the multiple constraints in the adoption decision. Despite several region-specific studies highlighting the potential benefits of SRI, the rate of adoption of SRI is at a slow pace and partial adoption is very common (Reddy at al., 2005). Studies find SRI to be labour intensive and, additionally, the shift away from traditional rice cultivation to SRI requires skilled labourers (Barrett et al., 2004; Palanisami et al., 2013). Therefore, the lack of skilled manpower available at the time of planting, poor water control, irrigation etc., have been highlighted as major constraints in the adoption of SRI (Palanisami et al., 2013). In addition, training on new method, awareness, experience etc., were also cited as major reasons for poor adoption (Devi and Ponnarasi, 2009).

Studies in general and the studies available for India in particular have pointed out various constraints faced by farmers in adopting SRI despite the proven benefits. In practice, even farmers with positive demand for adoption may not be able to adopt a new technology due to multiple constraints in adoption (Shiferaw et al., 2015). Nonetheless, studies investigating adoption of agricultural technologies in the context of multiple binding constraints are very limited. In fact, many adoption decision studies assume that farmers function in a perfect information setting and therefore face an unconstrained access to technology. According to Shiferaw et al. (2015), under such conditions of the zero (non-adoption) generating process, an adoption decision is modelled using probit and logit models for non-divisible technologies and tobit type models for divisible technologies.

Even in a perfect information setting, farmers with positive desired demand for adopting a new technology may fail to realise this potential demand owing to various constraints (Croppenstedt et al., 2003; Shiferaw et al., 2008; Shiferaw et al., 2015). The relaxation of constraints may lead to an increased adoption of new technology and, therefore, modelling technology adoption by dividing farmers into adopters and non-adopters fail to bring out the difference between actual and desired demand (Shiferaw et al., 2015). This may lead to inconsistency in estimated parameters.

Although a plethora of studies analysing the factors influencing adoption of SRI exists, there are hardly any study rigorously analysing the factors influencing the adoption of SRI in the context of multiple constraints. This is especially true for India. An understanding of the factors influencing adoption is necessary to overcome the hurdles that farmers face in the process. The study, therefore, analyses the role of information, extension services, irrigation and the availability of labourers in conditioning technology adoption by rice farmers in selected States of India. The multiple thresholds that farmers need to overcome in their adoption are analysed using a modified version of multi-hurdle model (Cragg, 1971; Shiferaw et al., 2015), which explicitly incorporates the impact of constraints in adoption decisions. A study of this kind assumes greater significance for a country like India which plays a crucial role in the global rice economy. In addition, the factors influencing the adoption of technologies may vary quite considerably across regions and countries. Therefore, the conclusions drawn from studies on other countries cannot be applied to the Indian context.

The remainder of the chapter is organized as follows. Section 3.2 provides conceptual framework for household technology adoption in the presence of multiple binding constraints along with variable description and hypothesized relationships. Section 3.3 presents the model specification and the main analytical results are presented and discussed in section 3.4. Concluding observations and policy implications are presented in section 3.5.

3.2 Conceptual Framework

Knowledge and perception of innovations are fundamental and integral parts of the underlying decision-making process of adoption (Rogers, 2003). Farmers' decision to adopt innovations has been extensively studied in a wide range of literature (Feder et al., 1985; Shiferaw et al., 2008; Teklewold et al., 2013; Kassie et al., 2013; Shiferaw et al., 2015; Manda et al., 2015; Kassie et al., 2015).

The farmers' decision on whether to adopt a new technology or not is based on utility maximisation (Rahm and Huffman, 1984; Shiferaw et al., 2015). The i^{th} farmer will go for new technology if the utility derived from the new technology is greater than the old technology, i.e., $U_{1i} > U_{0i}$. By denoting A for adoption decision we can write:

$$A_d = \begin{cases} 1 \; if \; U_{0i} \; < U_{1i} \\ 0 \; if \; U_{1i} \geq U_{0i} \end{cases} \qquad (1)$$

In the first scenario (A_d=1) the utility from the new technology is higher whereas in the second scenario (A_i=0) the utility is smaller than or equal to the old technology. The probability that the farmer adopts superior technology (A_i=1) depends on a set of explanatory variables.

$$\begin{aligned} P_i &= P_r(A_d = 1) = P_r(U_{1i} > U_{0i}) \\ &= P_r[\alpha_1 F_i(R_i Y_i) + e_{1i} > \alpha_0 \, F_i(R_i Y_i) + e_{o,i} \qquad (2) \\ &= P_r\left[e_{1i} - e_{0,i} > F_i(R_i, L_i)(\alpha_1 - \alpha_0)\right] \\ &= P_r(\mu_i \; > -F_i(R_i L_i)\beta) \\ &= F_i(X_i \beta) \end{aligned}$$

Where X is the n x k matrix of the explanatory variables and β is a k x 1 vector of parameters to be estimated, $Pr(.)$ is the probability function, μ_i is the random error term, and $F_i \, (X_i \, \beta)$ is the cumulative distribution function for μ_i evaluated at $X_i \, \beta$. The probability that a farmer will adopt a superior method is a function of the vector of explanatory variables and of the unknown parameters and error term.

The expected utility of the new technology is not, however, the only one factor that determines the adoption. This is especially true for small holder farmers in developing countries where they face multiple constraints in adoption. Even under a perfect information setting, farmers may not choose the new method due to several constraints in the form of lack of availability of skilled labourers, irrigation facility etc. In line with Shiferaw et al., (2008; 2015), the present study develops models for information access, availability of extension services, availability of labourers, and availability of irrigation. The information that is required for a farmer to make the adoption decision can be given as:

$$A^i \; = \begin{cases} 1 \; if \; A^i > 0 \\ 0 \; if \; A^i \leq 0 \end{cases} \qquad (3)$$

Once the farmer has the information the next step required is the minimum level of extension services which will enable the farmers to access the benefits of the new method. The observed pattern of extension services can be given as:

$$A^e = \begin{cases} 1 \; if \; A^e > 0 \\ 0 \; if \; A^e \leq 0 \end{cases} \qquad (4)$$

Now the farmer is aware of the new method and has sufficient guidance to implement the new method and to evaluate the benefits. Even when information and extension services are available, a producer with a positive desired demand may not be able to choose the new method due to other constraints such as lack of availability of labourers. The observed pattern of labour constraints can be given as:

$$A^l = \begin{cases} 1 \; if \; A^l > 0 \\ 0 \; if \; A^l \leq 0 \end{cases} \qquad (5)$$

Similarly, irrigation constraints can be given as:

$$A^{ir} = \begin{cases} 1 \; if \; A^{ir} > 0 \\ 0 \; if \; A^{ir} \leq 0 \end{cases} \qquad (6)$$

Whether the new method has been adopted or not by the producers can be given as:

$$A = A^i A^e A^l A^{ir} A^d = \begin{cases} 1, \text{ if the new method is adopted} \\ 0, \text{ if the new method is not adopted} \end{cases} \qquad (7)$$

Adoption of new method would occur only when the farmers are able to overcome all the initial constraints.

Model Specification

The farmer's demand for new method can be written as below.

$$y_i^* = x_i' \propto + u_i \qquad (8)$$

Where X_i is vector of variables that determine the demand function, ∝ is a parameter vector, *u* is an error term with mean 0 and variance σ_u. Similarly, the latent variable underlying a farmer's access to information, availability of extension services, availability of labourers and availability of irrigation can be modelled with equation (9) to (12).

$I_i^* = z_i' \beta + \epsilon_i$ (Access to information) (9)

$E_i^* = g_i' \theta + \omega_i$ (Availability of extension services) (10)

$L_i^* = h_i' \lambda + v_i$ (Availability of labourers) (11)

$IR_i^* = k_i' \delta + u_i$ (Availability of irrigation) (12)

In the above equations z, g, h and k are vector of variables that affect the availability of information, availability of extension services, availability of labourers, and availability of irrigation. And β, θ, λ and δ are the parameters to be estimated; $\boldsymbol{\epsilon}$, ω, v, u are the error terms with mean 0 and variance 1.

The observed demand for new method by a farmer (Y_i) is characterised by the interaction of model (8) to (12). The adoption of new method is observed only when all the initial hurdles have been overcome. This comprises the first group-adopters. Group 2 consists of farmers who do not have any information about SRI and hence cannot adopt SRI irrespective of whether they have availability of labourers or irrigation. In such case they will be indifferent to extension services. The third group will have availability of information but do not have sufficient knowledge in adoption due to lack of extension services. The fourth group consists of those farmers who have information and access to extension services and therefore have positive demand but are unable to adopt the new method due to the lack of availability of labourers. The fifth group will have information, extension services etc., and therefore positive demand but unable to adopt due to the lack of irrigation facility. The last group do not have positive demand for adoption of SRI and hence information, availability of labourers etc., are irrelevant for them.

In line with Shiferaw et al. (2008; 2015), the probability for adopting a new method can be given as:

$$P(A) = P(A)^d * P(A)^i * P(A)^e * P(A)^l * P(A)^{ir} \qquad (13)$$

The joint probability for adoption is estimated using conditional (recursive) mixed process estimator (CMP) developed by Roodman (2009 & 2011) and this method has been adopted in several empirical studies.[2] The model estimated through CMP will analyse the joint

[2] See for example, Ruppert, Peter, Elena Stancanelli, and Etienne Wasmer, (2009). Labor Market Outcomes: A Transatlantic Perspective. *Annals of Economics and Statistics*, No.95/96, pp.201-220, and Rosa Dias, P. (2010).

probability of adoption of SRI by incorporating multiple constraints in the model. CMP estimates multi-equation, recursive mixed process models. "Mixed process" means that different equations can have different kinds of dependent variables. CMP can only fit “recursive" models with clearly defined stages. A and B can be determinants of C and C a determinant of D--but D cannot be a determinant of A, B, or C (Roodman. 2011). Equations from 9 to 12 are estimated using probit models while a truncated normal model estimates the intensity as well as the depth of adoption (equation 8, where Y_i represents the adoption of farmer in terms of both the intensity of adoption as well as the depth of adoption). The depth of adoption is defined in terms of the number of SRI packages adopted by a farmer[3]. The intensity of adoption is defined as the number of acres devoted for SRI cultivation by a farmer.

Description of variables

The selection of variables included in our analysis is based on literature review and insights from other studies on farm household behaviour under imperfect market setting (Shiferaw et al., 2008; Shiferaw et al., 2015). Imperfect information, labour markets etc., will have direct impact on adoption as marginal cost of adoption will be higher for those households that face these constraints (Shiferaw et al., 2015). Therefore, we include many household and farm characteristics that have an impact on adoption decisions. Several studies have included household characteristics such as **age of the head** of the household, **gender of the head** of the household, **size of the household**, **education** etc., as important factors influencing the adoption decision by farmers (Feder et al., 1985; Uaiene, 2011; Teklewold et al., 2013; Ogada et al., 2014; Manda et al., 2015). Another important human capital which is relevant in influencing the adoption and the extent of adoption is **number of active family labourers** (Langyintuo and Mungoma, 2008; Noltze et al., 2012). Adoption of a new technology can be

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Modelling opportunity in health under partial observability of circumstances. *Health Economics*, 19, 252–264, doi: 10.1002/hec.1584.

[3] The depth of adoption of SRI is analysed using the total packages as dependent variable. The SRI emerged as a set of six practices. They are as follows:

1. Transplanting of young seedlings
2. Shallow planting of seedlings
3. Single seedling at wider spacing
4. Weeding by mechanical weeder
5. Use of organics
6. Efficient water management: Alternate wetting and drying

For the purpose of our analysis, we have decided to split the third package into two—single seedling and wider spacing. We observed that many farmers, although allowing wider spacing, were planting more than one seedling.

less attractive to those who do not have sufficient family labourers (Langyintuo and Mungoma, 2008). Also the **household size** is used as a proxy to capture labour endowment (Pender and Gebremedhin, 2008). As far as the importance of total **farm size** is concerned, studies on SRI shows a positive relationship between the size of the farm and intensity of SRI in Timor Leste (Noltze et al., 2012), whereas studies on the adoption of improved maize varieties in Zambia showed a negative relationship (Langyintuo and Mungoma, 2008).

Higher initial **Assets owned** by the farmer is expected to relax many of the above-mentioned constraints and, therefore, is an important factor in deciding the adoption (Langyintuo and Mungoma, 2008). Also, we consider the impact of farmers who have **farming as main occupation** on adoption decisions. The study by Noltze et al. (2013) show that household heads whose main occupation is farming are much less likely to adopt SRI. **Access to off-farm activities and income** in general are expected to have a positive impact on adoption decisions (Davis et al., 2009). The study by Langyintuo and Mungoma (2008) found a positive relationship in the case of adoption of improved maize varieties and the study by Noltze et al. (2012) found a positive relationship in the case of SRI adoption. However, the studies by Mathenge et al. (2014) and Manda et al. (2015) found a negative relationship between the two. Farmers' aversion to risk has also been highlighted by some studies as the reason for poor adoption (Johnson and Vijayaraghavan, 2011). To capture this effect, we include a variable, **fear of poor yield**, in our model to see how this has an impact on adoption decision.

From the studies mentioned earlier, we understand that SRI is labour intensive. Therefore, an important factor for adoption of SRI even when the farmer has positive demand for adoption is the **availability of labourers**.

Similarly, a farmer with positive demand may be constrained by lack of **availability of credit, access to extension services, access to information, access to seed** etc., and these factors play a significant role in adoption decisions (Langyintuo and Mungoma, 2008; Mazvimavi & Twomlow, 2009; Shiferaw et al., 2015). Since SRI is a knowledge-based innovation, extension services play even an even greater role in wider adoption (Noltze et al., 2012). Studies in the context of technology adoption in general have confirmed this view (Langyintuo and Mungoma, 2008). Moser and Barrett (2003) found a positive relationship between information availability and SRI adoption in Madagascar. Similar is the case with

access to irrigation. There are studies that highlight the importance of **irrigation** and irrigation management in deciding adoption of SRI (Tsujimoto et al., 2009; Noltze at al., 2012; Uphoff, 2012). Some studies also found **terrain type** to be important in deciding adoption of SRI (Moser and Barrett, 2003). Significant differences in adoption intensity between regions have been reported by some studies (Langyintuo and Mungoma, 2008). Also, there are studies on technology adoption that has captured the differences in regions through **district dummies.** Therefore, in our analysis we include district dummies to capture the differences in adoption across regions.

From the review of literature undertaken above we model lack of access to information, access to extension services, availability of labour, and availability of irrigation as the major constraints in adoption along with several other household, farm, and institutional factors. The key variables hypothesized to affect ***access to information*** include human capital variables such as age, gender and education; social capital variables such as whether household members hold an official position; number of assets owned; communication technology (ICT) such as radio, TV and mobile; farm size; and number of other crops cultivated. Similarly, access to ***extension services*** is expected to depend upon human capital variables mentioned above as well as social capital variable such as membership in input supply cooperatives, ICT variables, farm size, whether farming is main occupation, and other crops cultivated. ***Access to labourers*** is expected to link with the wage rates, human capital variables, number of family labourers, access to off-farm activity, assets etc. Similarly, ***availability of irrigation*** is expected to depend upon assets and human capital variables (assets, age, gender, education etc.), experience in agriculture, soil and terrain type, availability of credit etc. The final equation of ***intensity of SRI adoption*** (in terms of acres allotted for SRI) after overcoming multiple hurdles is expected to depend upon human capital variables, experience in agriculture, assets, credit, number of improved varieties known etc**.** Similarly, the ***depth of adoption*** in terms of the number of packages is estimated within the same constraints. [4]

[4] Although credit can be a major constraint in adoption even for a farmer with positive demand, we do not consider credit constraint as a hurdle in our present analysis. Rather we include it as a factor deciding adoption decision. This is due to the fact that our field-level observations did not find credit as a major constraint faced by farmers. Rather non-adopted farmers highlighted the reasons such as lack of availability of labourers, lack of information, irrigation etc., as the major reasons for non-adoption. This is intuitively true. Unlike other technologies SRI do not drastically change the cost of cultivation. Similarly, access to seed is considered as an important hurdle that need to be overcome to adopt technology in the context of improved maize or other varieties (Shiferaw et al., 2015). This hurdle makes sense as the adoption of a new variety depends on the access

3.4 Estimation Results and Discussion

3.4.1 Descriptive Statistics

Total sample size was 386, of which 193 households were non-adopters of SRI. Among non-adopters around 38 farmers didn’t have any information about SRI. This figure is interesting since it shows that around 80% of farmers were aware of SRI. Therefore, the lack of information did not play a role in non-adoption. Rather it indicates other constraints. Among the non-adopters, around 122 farmers didn’t have access to any sort of extension services, 115 farmers faced difficulty with respect to irrigation, and 117 farmers reported difficulty in getting labourers. Availability of labourers was a problem even among the adopters of SRI. Descriptive statistics of the explanatory variables that are hypothesised to influence the constraints as well as the adoption of SRI are presented in Table 3.1.

Table: 3.1: Definition and Summary Statistics of Variables used in the Analysis

Variables	Description	Mean	Std. Dev
Age HoH	Age of the head of the household	50	11.35
HoH Gender	Gender of the head of household, Male=1	.90	.29
Education higher than 10^{th}	No. of members educated higher than 10^{th}	.79	1.1
Farm Size	Size in terms of marginal, small, semi-medium, medium and large	.78	.84
ICT (TV, Radio)	Information and communication technology, yes=1	.30	.46
Mobile	Yes=1	.70	.46
Other Crops Cultivated	Only rice=1	.34	.48
Assets owned	Number of assets like tractors, bullock carts etc.	1.4	1.9
Anyone holding official position from family	Yes=1	.02	.19
Farming is main occupation	Yes=1	.80	.40
Membership in input supply co-operative (s)	Yes=1	.40	.49
No. of years in Agriculture	Experience in agriculture	24.66	11.74
Land on rent	Land cultivated on rent	.14	.59
Assets rented	No of assets rented	.58	.97
Value of assets owned (in lakhs)	Total value of farm assets	2.53	6.5
Distance from main market (in km)	Distance from main market	11.48	10.58

to seed. However, in our case we do not treat seed access as a hurdle as SRI is not specific to any particular rice variety.

Active family labourers	No of active family labourers	2.51	1.26
Access to off-farm activity	Yes=1	.32	.47
Wage rate for female	Wage rate in rupees	138.51	59.77
Wage rate for male	Wage rate in rupees	167.51	75.50
Soil type	1. White and Black 2. Red 3. Black 4. Sandy mix 5. Red & Black 6. Red & sandy.	3.92	1.55
Terrain type	Levelled=1, step=0	.29	.45
Agricultural loan	Yes=1	.40	.49
No of improved varieties known	In terms of number of rice varieties known by farmer	.68	.83
Fear poor yield	Yes=1	.66	.47
No of Observations: 386			

3.4.2 Multiple Hurdles in terms of the Intensity of Adoption (in terms of acres of land under SRI)

The multiple hurdle model results for intensity of SRI adoption are presented in Table 3.2. One of the first and major hurdles that need to be overcome in order to adopt a new method or technology is adoption. The information access model estimated shows that the size of the farm and age of the farmer is very crucial in getting access to information. The results show that smaller farmers and older people have less access to information as compared to large and young farmers. The result for farm size is in line with existing studies on technology adoption in agriculture (Shiferaw et al., 2015). The dummy variables for districts showed that as compared to Chikmagalur (Karnataka), the availability of information was significantly lower in districts such as Hassan (Karnataka), Shahdol (Madhya Pradesh), and Keonjhar (Orissa). Interestingly, Hassan, Shahdol and Keonjhar are the districts selected by the Government of India to promote SRI within the National Food Security Mission. As compared to Chikmagalur, Sidhi (Madhya Pradesh) had better information about SRI.

Education did not play a major role in getting access to information. Nonetheless, education was found to be important in getting access to extension services. Apart from education, membership with input supply cooperatives, access to off-farm activities etc., were also found to have a positive impact in getting access to extension services. Those farmers who had farming as main occupation also had greater access to extension services indicating the importance of the amount of time that a full-time farmer is able to devote for agriculture in getting access to extension services. As far as dummy variables for districts are concerned, although Chikmagalur was a relatively better informed district, the availability of extension services were higher in Hassan (Karnataka), Shahdol (Madhya Pradesh), and Keonjhar (Orissa). Therefore, better extension services were noted in those districts where SRI is promoted under government's food security mission.

Age, cultivation of only rice, farming as main occupation and access to off-farm activities were found to be significant in providing greater availability of labourers. As compared to Chikmagalur, access to labour was significantly higher in Sidhi (Madhya Pradesh). Soil type, terrain type and farming as main occupation had a positive impact on having access to irrigation. It has been pointed out that SRI is mainly suitable for environments with high acid, iron-rich soil availability (Dobermann, 2004). Studies in the Indian context also show the importance of soil type in adoption of SRI (Palanisami et al., 2013). Terrain type is also very crucial to have the type of irrigation required for SRI. Land selected for SRI should be well levelled and should not have the problem of waterlogging. Also, when the plot is irrigated the water should spread uniformly across the field. As compared to Chikmagalur, access to irrigation was higher in Keonjhar (Orissa).

Although farm size had a positive impact in accessing information, it had a negative impact on the intensity of SRI adoption. This indicates that more small farmers adopt SRI than large farmers. SRI, which originated in Madagascar, was aimed at promoting rice production among small farmers. However, studies on SRI showed a positive relationship between the size of the farm and adoption of SRI in terms of area in Timor Leste (Noltze et al., 2012) whereas studies on the adoption of improved maize varieties in Zambia showed a negative relationship between farm size and adoption (Langyintuo and Mungoma, 2008). Assets owned and rented and number of improved varieties of rice known had a positive and significant impact on the intensity of SRI adoption. There is consensus in the literature on technology adoption on the view that higher initial assets owned by the farmer are expected to relax many of the constraints such as credit and, therefore, is an important factor in making the adoption decision (Langyintuo and Mungoma, 2008).

However, the fear of poor yield is negatively related to the intensity of SRI adoption. Aversion to risk by farmers is highlighted as one of the reasons for poor adoption of SRI (Johnson and Vijayaraghavan, 2011). As far as the district dummies are concerned, there have been no major differences in the intensity of adoption among the districts except for the fact that Shahdol (Madhya Pradesh) and Mayurbhanj (Orissa) had greater intensity of adoption of SRI as compared to Chikmagalur (Karnataka). Interestingly, Shahdol is an NFSM district where SRI is promoted under NFSM whereas Mayurbhanj is not. The results indicate that promotion of SRI through NFSM is effective in some districts and not in others.

Table 3.2: Multiple Hurdle Model for Intensity of Adoption (no of acres for SRI)

A. Access to Information	**Coefficient**	**Z-Statistic**	**Marginal Effects**
Age of head	-.012(.007)	-1.79*	-.004
HoH gender (Male =1)	-.265(.256)	-1.04	-.076
Education	-.099(.076)	-1.30	-.028
Farm Size	.203(.102)	1.99**	.058
ICT (Radio, TV) (yes=1)	.116(.253)	.46	.033
ICT (Mobile) (yes=1)	.095(.169)	.56	.027
Other crops cultivated (only rice=1)	.213(.165)	1.29	.061
Assets owned (numbers)	-.022(.038)	-0.59	-.006
Anyone holding official position (yes=1)	-.019(.360)	-0.05	-.005
Hassan	-1.08(.313)	-3.47***	-.312
Shahdol	-1.73(.381)	-4.53***	-.497
Sidhi	.688(.405)	1.70*	.198
Keonjhar	-.899(.330)	-2.72**	-.258
Mayurbhanj	.274(.341)	0.80	.079
Constant	.971(.501)	1.94**	
B. Access to Extension services			
Age of head	-.005(.008)	-0.64	-.001
HoH gender (Male =1)	.413(.299)	1.38	.099
Education	.170(.083)	2.05**	.041
Farm Size	.051(.112)	1.46	.012
ICT (Radio and TV) (yes=1)	-.152(.272)	-0.56	-.037
ICT (Mobile) (yes=1)	.199(.185)	1.08	.048
Other crops cultivated (only rice=1)	-.055(.182)	-0.30	-.013
Assets owned (numbers)	-.020(.041)	-0.49	-.005
Membership in input supply cooperatives (yes=1)	1.54(.176)	8.78	.373
Farming as main occupation	.370(.209)	1.77*	.089
Hassan	1.09(.336)	3.25***	.264
Shahdol	1.20(.426)	2.82**	.290
Sidhi	-.153(.429)	-0.36	-.037
Keonjhar	.800(.368)	2.17**	.193
Mayurbhanj	.356(.365)	0.98	.086
Constant	-1.44(.556)	-2.59**	
C. Availability of Labourers			
Age of head	-.018(.007)	-2.54**	-.005

HoH gender (Male =1)	-.367(.251)	-1.46	.111
Education	.088(.071)	1.23	.026
Active family labour	.061(.057)	1.07	.019
Other crops cultivated (only rice=1)	.359(.160)	2.24**	.108
Assets owned	.008(.037)	0.22	.002
Assets rented	.034(.086)	0.40	.011
Farming is main occupation (yes=1)	.559(.266)	2.10**	.169
Access to off-farm activity (yes=1)	.630(.223)	2.82**	.190
Wage Female	-.004(.003)	-1.13	-.001
Wage Male	.001(.004)	0.26	.003
Hassan	-.252(.323)	-0.78	-.076
Shahdol	.136(.468)	0.29	.041
Sidhi	1.66(.539)	3.08***	.502
Keonjhar	-.633(.428)	-1.48	-.191
Mayurbhanj	.083(.441)	0.19	.025
Constant	.553(.780)	0.71	
D. Availability of Irrigation			
Age of head	-.003(.008)	-0.41	-.001
HoH gender (Male =1)	-.373(.242)	1.54	.132
Education	.022(.068)	0.32	.008
Active family labour	.004(.055)	0.07	.001
No of years in agriculture	-.008(.007)	-1.16	-.003
Farm Size	.090(.104)	0.86	.032
Rented land (in acres)	-.034(.115)	-0.30	-.012
Soil type	.190(.051)	3.67***	.067
Terrain type	.710(.207)	3.42***	.251
Other crops cultivated (only rice=1)	-.116(.157)	-0.74	-.041
Value of assets in lakhs	.0004(.012)	0.04	.000
Farming is main occupation (yes=1)	.314(.184)	1.70*	.111
Agricultural loan (yes=1)	.03(.156)	0.47	.026
Hassan	-.384(.308)	-1.25	-.136
Shahdol	.226(.296)	0.76	.080
Sidhi	.231(.323)	0.72	.082
Keonjhar	.489(.283)	1.73*	.173
Mayurbhanj	.078(.284)	0.27	.028
Constant	-1.13(.476)	-2.37**	
E. Intensity of SRI adoption			
Age of head	-.002(.001)	-1.50	-.001
HoH gender (Male =1)	.015(.026)	0.58	.006

Education	.007(.011)	0.62	.003
Farm size	-.057(.016)	-3.71***	-.023
No of years in agriculture	-.0003(.001)	-0.27	-.000
Rented land (in acres)	0007(.018)	0.37	.003
Terrain type	.036(.030)	1.19	.014
Wage Female	-.0004(.0006)	-0.69	-.000
Wage Male	.0002(0005)	0.43	.000
Assets owned	.010(.005)	1.87*	.004
Assets rented	.029(.013)	2.23**	.012
Farming is main occupation (yes=1)	.028(.027)	1.05	.011
No. of improved varieties known	.042(.016)	2.64**	.017
Other crops cultivated (only rice=1)	-.018(.023)	-0.77	-.007
Membership in input supply cooperatives	.072(.024)	2.99***	.028
Distance from main market	.001(.001)	0.93	.000
Fear of poor yield	-.045(.023)	-1.93**	-.017
Hassan	-.019(.050)	-0.39	-.008
Shahdol	.130(.072)	1.80*	.051
Sidhi	.089(.074)	1.19	.035
Keonjhar	.105(.066)	1.59	.041
Mayurbhanj	.122(.070)	1.74*	.048
Constant	.112(.109)	1.02	
No. of observations	386	LR chi2(85)	507.49
Log Likelihood	-695.7997	Prob>Chi2	0.000

Note: *, **, and *** indicate significance levels at the 10%, 5%, and 1% levels respectively. Standard errors are in parenthesis

3.4.3 Multiple Hurdles in terms of the Depth of Adoption (in terms of number of packages)

The multiple hurdle model results for intensity of SRI adoption are presented in Table 3.3. The results for the initial four hurdles were more or less the same in both the models. The only striking difference was in the case of access to extension services by a male head of the household in package adoption. The results show that access to extension services is better when head of the household is a male (see Table 3.3).

As far as the depth of adoption of SRI is concerned, wage rates, assets of the households, membership in farmers' organisations, cultivation of only rice etc., had significant impact. Interestingly, wage rates for male labourers had a positive impact whereas wage rates for female labourers had negative impact. Majority of labourers employed in paddy cultivation in the selected districts were female labourers. The weeding operations under conventional rice cultivation have been traditionally done by women. However, as a result of SRI adoption, rice farmers hire more and more of male labourers for mechanical weeding (Senthikumar et al., 2008). Therefore, the shift from manual weeding to mechanical weeding resulted in greater demands for male labourers and thus the positive relationship between male wage rates and SRI adoption. This also points out the skill intensive nature of SRI adoption and gender-biased technical change.

The relationship between the number of years farmers are in agriculture and the SRI adoption was also negative and statistically significant. Perhaps this indicates a clear preference for SRI by young farmers. There was a positive and significant relationship between farmers with farming as main occupation and the intensity of adoption of SRI. Nonetheless the result contradicts the findings of Noltze et al. (2013) for Timor Leste. As per the study by Noltze et al. (2013), the household head whose main occupation is farming is much less likely to adopt SRI. The contradictory results point out the fact that the nature, intensity and the factors contributing to it can vary quite considerably across regions.

Assets owned and rented also had a positive impact on adoption. This finding is in line with the existing studies (Langyintuo and Mungoma, 2008). Number of improved varieties known, membership in input supply cooperatives, and cultivation of only rice had positive impact on adoption. However, higher the fear of poor yields lower the intensity of adoption. The result that was contrary to our expectation was the distance from main market. The results showed that distance from main market had a positive impact on adoption of SRI. However, the results are not counter-intuitive. We noticed that small farmers, farmers who have farming as main occupation as well as those who are cultivating only rice were more enthusiastic about adopting SRI. So it is very obvious that farmers who are remotely located from the market were adopting SRI as a survival strategy. Unlike other technology adoption, SRI does not require any particular variety of seeds as SRI can be implemented on any rice variety. So apart from information and extension services, SRI is not market dependent. Therefore, this could be the reason why distance has a positive impact on adoption. In addition, farmers who have proximity to main market will have greater tendency to produce and sell those crops, other than rice, in the market for better prices. None of the distance dummies were significant indicating only little difference in depth of adoption across these districts.

Table 3.3: Multiple Hurdle Model for Depth of Adoption (SRI Packages)

A. Information	Coefficient	Z-Statistic	Marginal Effects
Age of head	-.013(.007)	-1.81*	-.004
HoH gender (Male =1)	-.275(.254)	1.08	-.079
Education	-.100(.076)	-1.31	-.029
Farm Size	.208(.102)	2.04**	.060
ICT (Radio and TV) (yes=1)	.120(.254)	0.47	.034
ICT (Mobile) (yes=1)	.079(.169)	0.47	.023
Other crops cultivated (only rice=1)	.216(.165)	1.31	.062
Assets owned (numbers)	-.022(.038)	-0.58	-.006
Anyone holding official position (yes=1)	-.029(.359)	-0.08	-.008
Hassan	-1.08(.314)	-3.44***	-.310
Shahdol	-1.73(.382)	-4.55***	-.498
Sidhi	.696(.404)	1.72*	.200
Keonjhar	-.888(.330)	-2.69**	-.255
Mayurbhanj	.277(.340)	0.82	.080
Constant	.973(.500)	1.94**	
B. Extension services			
Age of head	-.004(.008)	-0.46	-.001
HoH gender (Male =1)	.503(.299)	1.68*	.121
Education	.152(.086)	1.86*	.037
Farm Size	.050(.112)	0.45	.012
ICT (Radio and TV)(yes=1)	-.202(.267)	-0.76	-.049
ICT (Mobile) (yes=1)	.230(.184)	1.25	.055
Other crops cultivated (only rice=1)	-.063(.182)	-0.35	-.015
Assets owned (numbers)	-.020(.042)	-0.49	-.005
Membership in input supply cooperatives (yes=1)	1.56(.176)	8.80***	.374
Farming as main occupation	.373(.209)	1.79*	.090
Hassan	1.11(.334)	3.32***	.267
Shahdol	1.14(.424)	2.70**	.275
Sidhi	-.232(.426)	-0.55	-.056
Keonjhar	.734(.365)	2.01**	.176
Mayurbhanj	.337(.361)	0.93	.081
Constant	-1.45(.552)	-2.64**	
C. Labourers			
Age of head	-.017(.007)	-2.45**	-.005
HoH gender (Male =1)	-.284(.250)	-1.13	.086
Education	.085(.071)	1.20	.026
Active family labour	.063(.058)	1.10	.019
Other crops cultivated (only rice=1)	.355(.160)	2.22**	.108
Assets owned	.008(.037)	0.22	.002
Assets rented	.037(.087)	0.43	.011
Farming is main	.540(.267)	2.02**	.164

occupation (yes=1)			
Access to off-farm activity (yes=1)	.620(.224)	2.77**	.188
Wage Female	.001(.004)	0.34	.000
Wage Male	-.004(.004)	-1.21	-.001
Hassan	-.239(.321)	-0.74	-.072
Shahdol	.136(.469)	0.29	.041
Sidhi	1.64(.541)	3.05***	.500
Keonjhar	-.626(.428)	-1.46	-.190
Mayurbhanj	.101(.441)	0.23	.031
Constant	.529(.777)	0.68	
D. Irrigation			
Age of head	-.002(.008)	-0.32	-.001
HoH gender (Male =1)	-.326(.241)	-1.35	.116
Education	.019(.068)	0.27	.007
Active family labour	-.001(.055)	-0.02	-.000
No of years in agriculture	-.008(.007)	-1.22	-.003
Farm Size	.090(.104)	0.86	.032
Rented land (in acres)	-.034(.115)	-0.30	-.012
Soil type	.185(.052)	3.58***	.066
Terrain type	.714(.207)	3.44***	.253
Other crops cultivated (only rice=1)	-.113(.156)	-0.72	-.040
Value of assets in lakhs	-.001(.011)	-0.05	-.000
Farming is main occupation (yes=1)	.319(.184)	1.74*	.113
Agricultural loan (yes=1)	.070(.156)	0.44	.025
Hassan	-.377(.309)	-1.22	-.134
Shahdol	.223(.296)	0.75	.079
Sidhi	.225(.324)	0.70	.080
Keonjhar	.494(.283)	1.75*	.175
Mayurbhanj	.086(.285)	0.30	.031
Constant	-1.12(.477)	-2.34**	
E. Depth of SRI Adoption			
Age of head	-.005(.007)	-0.76	-.001
HoH gender (Male =1)	-.017(.159)	0.11	-.003
Education	.006(.067)	0.10	.001
Farm size	-.010(.096)	-0.11	-.002
No of years in agriculture	-.015(.006)	-2.48**	-.003
Rented land (in acres)	.080(.112)	0.71	.016
Terrain type	-.010(.185)	-0.05	-.002
Wage Female	-.008(.003)	-2.26**	-.001
Wage Male	.006(.003)	2.03**	.001
Assets owned	.171(.033)	5.08***	.034
Assets rented	.206(.081)	2.55**	.042
Farming is main occupation (yes=1)	.552(.169)	3.26***	.111

No of improved varieties known	.196(.099)	1.99**	.040
Other crops cultivated (only rice=1)	-.255(.146)	-1.75*	-.051
Membership in input supply cooperatives	.472(.147)	3.21***	.095
Distance from main market	.013(.006)	2.11**	.003
Fear of poor yield	-.266(.140)	-1.89**	-.054
Hassan	-.252(.314)	-0.80	-.051
Shahdol	.151(.446)	0.34	.030
Sidhi	-.001(.459)	-0.00	-.000
Keonjhar	-.133(.408)	-0.32	-.027
Mayurbhanj	-.050(.431)	-0.12	-.010
Constant	.907(.673)	1.35	
No of observations	386	LR chi2(85)	544.90
Log Likelihood	-1392.70	Prob>Chi2	0.0000

Note: *, **, and *** indicate significance levels at the 10%, 5%, and 1% levels respectively. Standard errors are in parenthesis.

3.5 Conclusion

The chapter analysed the determinants of the intensity as well as the depth of adoption of SRI in India. It has been observed that adoption of SRI in the selected districts of India is constrained by imperfect markets for information, and lack of access to extension services, labourers and irrigation facility. Most previous studies assume that markets are perfect and thereby non-adopters of a technology are not interested in adoption. However, the studies fail to capture the reality of farmers’ lack of information and access to some of the factors which are crucial for adoption. Therefore, even a farmer with positive demand for adoption may not be able to adopt owing to several constraints. These lacunae may lead to inconsistent parameter estimates (Shiferaw et al., 2008; Shiferaw et al., 2015). Therefore, in line with some of the recent studies (Shiferaw et al., 2008; Shiferaw et al., 2015), the present study makes use of a multi hurdle model which is a modified double hurdle model. There have not been any such attempts to analyse the multiple constraints in the context of SRI, which is especially true for India.

The descriptive analysis showed that out of 386 households interviewed, only 38 farmers did not have any information regarding SRI. This constitutes only 10 per cent. The results, therefore, provide us with some policy relevant insights. The main reason for non-adoption was not lack of information about SRI; rather, it was due mainly to other constraints such as access to extension services, availability of labourers and irrigation. Around 63 per cent of non-adopters did not have access to extension services. Extension services are very crucial for wider promotion and application of SRI. Unlike other technology adoption in agriculture, SRI is not purely a technology or use of an improved variety of a seed; instead, it is a set of innovative ideas. Similarly, around 60 per cent of non-adopters faced the problem of availability of labourers and irrigation facility. Difficulty in getting labourers was a problem even among adopters of SRI. As far as the irrigation is concerned, although SRI is supposed to be less irrigation intensive, the analysis showed that the type of land is very important in having an effective irrigation. Land selected for SRI should be well levelled and should not have the problem of waterlogging. Also, while irrigating the plot, water should spread evenly across the field. Additionally, farmers must have their own irrigation facility so that they can provide irrigation whenever it is needed.

The results from the multi hurdle analysis showed that age and farm size are important in getting access to information indicating younger and large farmers had greater access to information. Gender of the head of the household, education, membership in farmers' organisations etc., were crucial factors in getting access to extension services. Age of the head of the household, cultivation of only rice, farming main occupation, access to off-farm activity etc., are found to be important factors in getting labourers. Those who have farming as main occupation and rice as main farming find it relatively easier to get labourers indicating the role of social network. Full-time farmers, especially rice farmers, might have developed a rapport with the labourers.

District-wise analysis of constraints showed that the disparities were the highest in the case of accessing information, followed by extension services. This highlights the role of extension services in wider dissemination of SRI practices.

After overcoming the hurdles of information access, access to extension services, availability of labourers and irrigation, the final decisions relating to number of acres and packages will be made by the farmers. The results showed that the factors influencing the intensity (in terms of acres of land for SRI) of SRI adoption was slightly different from the factors influencing the depth of SRI adoption (in terms of packages). Nonetheless, the common factors that influenced both intensity and depth were assets owned and rented, number of improved rice varieties known, membership in input supply cooperatives and the fear of poor yield. So, it is clear that financial capital such as initial wealth and social capital such as membership in farmers' organisations are very crucial in affecting the adoption of SRI. Wage rates for labourers were crucial in the depth of adoption of SRI. Wage rates of woman labourers were negatively related to adoption whereas wage rates for male labourers were positively related to adoption. This is perhaps due to the fact that the shift away from manual weeding to mechanical weeding creates more demand for male labourers. So, the skill-intensive nature of mechanical weeding leads to higher demand for male labourers and, thus, higher wage. So this indicates the possibility of a gender-biased technical change.

Chapter 4
Adoption of Multiple SRI Packages

4.1 Introduction

Despite an increase in the number of studies that describe SRI adoption and its benefits, our understanding of what drives a farmer to adopt different SRI components remains limited. A better understanding of factors that influence farmer's adoption of multiple SRI practices is, therefore, important for designing policies that could stimulate their adoption and thereby rice productivity and farm income. Farmers often choose only parts of a package or apply combination of practices only on small parts of their cultivated area (Smale, Heisey, & Leathers, 1995). Also technology adoption decisions are interdependent and combination of practices may influence each other (Teklewold et al., 2013). Attempting univariate modelling would exclude useful economic information about interdependent and simultaneous adoption decisions (Dorfman, 1996). Therefore, an analysis of factors influencing adoption decisions without controlling for technology interdependence and simultaneous adoption might lead to inconsistent parameter estimates (Teklewold et al., 2013).

There have been attempts to model the interrelationship in the adoption of multiple agricultural technologies, with one of the pioneering attempts being made by Feder (1982). In recent years, more studies have looked at the joint estimation of multiple agricultural technologies (Teklewold et al., 2013; Manda et al., 2015). The study by Teklewold et al (2013) applied a multivariate and ordered probit model to the household adoption of various sustainable agricultural practices in rural Ethiopia.

Not much attempts have been made to analyse the factors influencing the adoption of various components of SRI using a multivariate framework, which is especially true for India. The present study contributes to the growing adoption literature on SRI by making a detailed analysis of the factors influencing the adoption of various packages of SRI.

The remainder of the chapter is organized as follows. Section 4.2 provides conceptual and econometric framework for the analysis along with variable description and expected relationships. Section 4.3 presents the descriptive statistics along with the discussion of explanatory variables used in this study. The analytical results are discussed in section 4.4. Concluding observations and policy implications are presented in section 5.5.

4.2. Conceptual and Econometric Framework

In line with existing studies on agricultural technology adoption behaviour, the present study makes use of a random utility theory to explain adoption where the utility of a farm household is specified as a linear function of the household and farm-specific characteristics, institutional factors, attributes of technology as well as a stochastic component (Marenya and Barrett, 2007). Farmers will adopt a practice or a combination of practices that can provide maximum utility to them.

SRI consists of a set of six practices. They are:

1. Transplanting of young seedlings
2. Shallow planting of seedlings
3. Single seedling at wider spacing
4. Weeding by mechanical weeder
5. Use of organics
6. Efficient water management: Alternate wetting and drying

For the purpose of our analysis, we have decided to split the third package into two—single seedling and wider spacing. We observed that many farmers, despite allowing wider spacing, were planting more than one seedling.

The probability of choosing a specific practice or a combination of practices is equal to the probability that the utility of that particular alternative is greater than or equal to the utilities of all other alternatives in the choice set. In order to maximise the utility U_{ij}, an i^{th} farmer will compare alternative practices and combinations. Accordingly, an i^{th} farmer will choose a practice j, over any alternative practice k, if $U_{ij}>U_{ik}$, $k\neq j$.

In this study, farmers' choice of different interrelated SRI practices is modelled using a multivariate probit model (MVP), and the factors influencing the extent of combinations of SRI practices adopted is modelled using an ordered probit model. The estimation of both the models is undertaken using conditional (recursive) mixed process estimator developed by Roodman (2011).

4.2.1 Multivariate Probit Model

Decision to adopt different practices or components is inherently a multivariate decision. In single equation statistical models farmers' inability to access one set of services does not alter the likelihood of them accessing another set of services. However, the multivariate probit model (MVP) simultaneously models the influence of the set of explanatory variables on each of the different technology practices, while allowing for the potential correlation between unobserved disturbances as well as the relationship between the access to different practices (Teklewold et al., 2013). The MVP recognizes the correlation in the error terms of adoption equations and estimates a set of binary probit models (in our case seven probit models) simultaneously. The possibility for correlation is due to the fact that the same unobserved characteristics of farmers could influence the adoption of different SRI practices (Kassie et al., 2015). Failure to capture the interdependence of adoption of different SRI practices might lead to inconsistent parameter estimates (Kassie et al., 2015).

The farmer decides to adopt a k_{th} SRI practice with a latent (unobservable) dependent variable (Y_{ik}) as a function of a set of observable household, farm, institutional and other relevant factors and multivariate normally distributed error terms (ϵ_i) (Teklewold et al., 2013; Kassiet et al., 2015). The same can be expressed as:

$$Y_{ik} = X_{ik}\beta_k + \epsilon_{ik}, \ (k=1..K) \quad (1)$$

Where Y_{ik} denotes the latent dependent variable which can be represented by the level of expected benefit and/or utility derived from adoption. X represents a set of household, farm and institutional factors and β is the parameter that needs to be estimated. $\epsilon_{ik,}$ (k=1..K) are the multivariate normally distributed error terms. 1 to K packages are transplanting of young seedlings (T), shallow planting of seedlings (P), single seedling (S), wider spacing (W), use of organics (O), weeding by mechanical weeder (E), and efficient water management (M).

The second system of equations describing the observable binary outcome equation variables for each of the SRI practices choice of households is given as:

$$Y_{ik} = \begin{cases} 1 \ if \ Y_{ik} > 0 \\ 0 \ otherwise \end{cases} \quad (2)$$

In line with Teklewold et al. (2013) and Kassie et al. (2015), we describe a multivariate model, with the error terms jointly following a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity for identification of parameters. This can be expressed as:

(uT, uP , uS, uW, uO , uE, uM)˜.MVN (0, Ω) and the symmetric variance–covariance matrix Ω is given by;

$$\Omega = \begin{bmatrix} 1 & PTP & PTS & PTW & PTO & PTE & PTM \\ PPT & 1 & PPS & PPW & PPO & PPE & PPM \\ PST & PSP & 1 & PSW & PSO & PSE & PSM \\ PWT & PWP & PWS & 1 & PWO & PWE & PWM \\ POT & POP & POS & POW & 1 & POE & POM \\ PET & PEP & PES & PEW & PEO & 1 & PEM \\ PMT & PMP & PMS & PMW & PMO & PME & 1 \end{bmatrix}$$

Where, P denotes the pair-wise correlation coefficient of the error terms with respect to any two SRI-package adoption equations. In the presence of the correlation of error terms, the off-diagonal elements in the variance–covariance matrix of adoption equations become non-zero and equation (2) becomes an MVP model (Kassiet et al., 2013).

4.2.2 Ordered Probit Model

The MVP model specified above only considers the probability of adoption of different packages of SRI, with no distinction made between, for example, those farmers who adopt one package and those who adopt multiple packages in combination. Therefore, an ordered probit analyses the factors that influence the adoption of a combination of SRI packages (in terms of total number of packages adopted). The total number of packages in our case varies from one to seven. Additionally, the variables that affect the adoption of a SRI package may differently affect the intensity of adoption of packages (Teklewold et al., 2013). As discussed in Teklewold et al (2013), the information on the number of packages adopted could have been treated as a count variable. Count data are usually analysed using Poisson regression models but the underlying assumption is that all events have the same probability of occurrence (Wollni et al., 2010). However, in our case the probability for adopting first package can differ from the probability of adopting a second package or a third package and so on. The farmers who adopt more number of packages are definitely superior in terms of the intensity of adoption and they have already acquired enough information and experience in the practice of SRI. Therefore, we treat the number of packages adopted by farmers as an ordinal variable and use an ordered probit model in the estimation.

4.3 Descriptive Statistics: Description of Dependent and Explanatory Variables

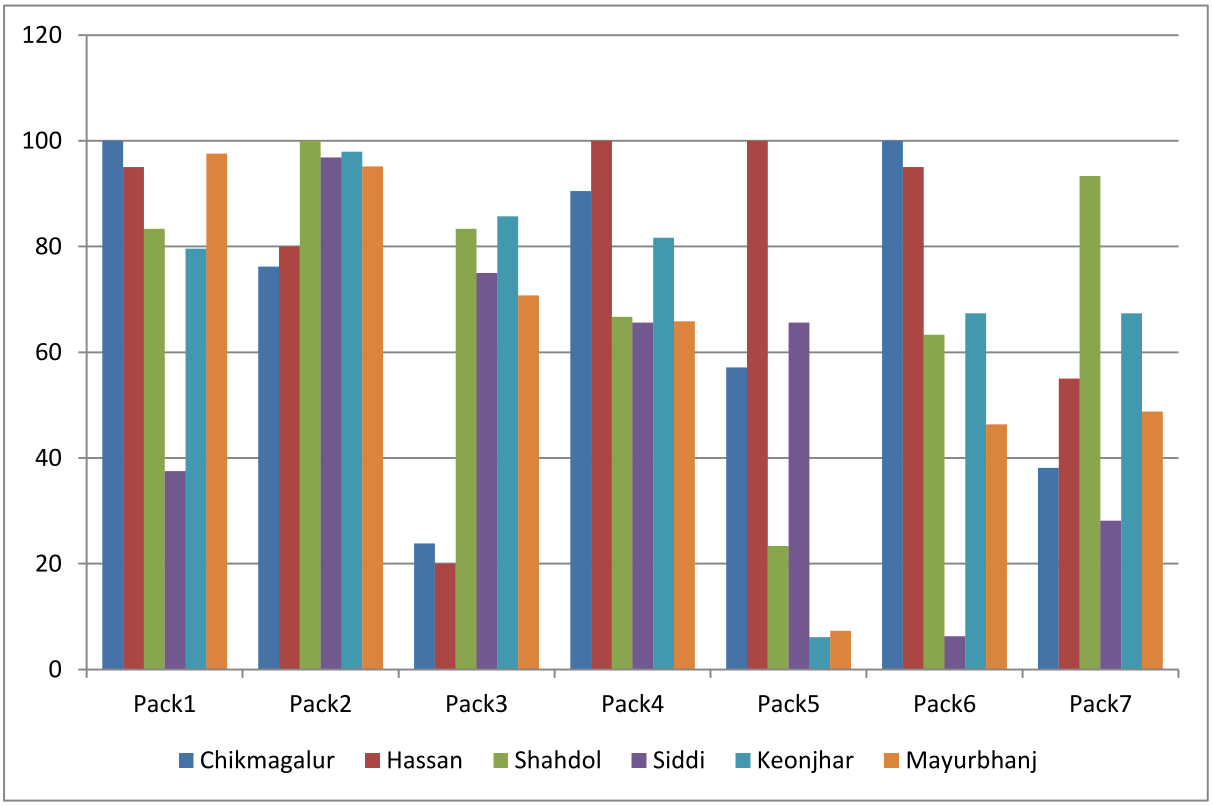
Descriptive statistics of the seven SRI packages as dependent variables and all explanatory variables are presented in Table 1

4.3.1 The Dependent Variables

The number of adopters of young seedling was 156; shallow planting was 180; single seedling was 129; wider spacing was 147; organics was 66; mechanical cono weeders was 113; wetting drying was 109. The highest adoption of SRI packages was observed in Keonjhar district of Orissa. In Keonjhar around 98 farmers adopted all the packages of SRI. The lowest adoption of SRI packages was observed in Hassan district of Karnataka. The adoption of SRI packages was generally low in Karnataka as compared to other States. The adoption of all packages of SRI was the highest in Orissa.

The detailed analysis of package-wise adoption of farmers in different regions show that the adoption of young seedling for SRI was the highest in Chikmagalur district of Karnataka followed by Mayurbhanj district of Orissa (see Figure 4.1). All the adopters of Chikmagalur had adopted young seedling whereas 98 per cent of adopters adopted young seedling in Mayurbhanj. The adoption of young seedling was the lowest in Sidhi district of Madhya Pradesh. The adoption of shallow planting was the highest in Shahdol district of Madhya Pradesh but the lowest in Chikmagalur. In Shahdol, all the adopters had adopted shallow planting whereas in Chikmagalur only 76 per cent of the adopters adopted shallow planting. Adoption of the planting of single seedling was the highest in Keonjhar district of Orissa and the lowest in Chikmagalur. In Keonjhar, around 86 per cent of adopters adopted single seedling while planting, whereas in Chikmagalur only 24 per cent used single seedling. The wider spacing between the plants was the highest in Hassan district of Karnataka (100 per cent) it was the lowest in Mayurbhanj and Sidhi (66 per cent each). The use of organics was also the highest in Hassan (100 per cent) and most of the other districts had relatively low levels of adoption of organics. The adoption of organic was the lowest in Keonjhar (6 per cent). Use of cono weeders was the highest in Chikmagalur (100 per cent) and followed by Hassan (95 per cent). The use of cono weeders was the lowest in Sidhi (6 per cent). Water management was the highest in Shahdol (93 per cent) whereas it was the lowest in Chikmagalur (38 per cent).

Figure 4.1: Percentage of Adoption of Each Package among the Sample SRI Adopted Households



Source: Survey data

4.3.2 Explanatory Variables

The model specification draws on the existing adoption literature (Feder et al., 1985; Adesina and Zinnah, 1993; Moser and Barrett, 2003; Langyintuo and Mungoma, 2008; Pender and Gebremedhin, 2008; Uaiene, 2011; Meshram et al., 2012; Kassie et al., 2013; Teklewold et al., 2013; Ogada et al., 2014; Manda et al., 2015; Kassie et al., 2015 etc.).

We control for household heterogeneity by including variables such as age of the head of the household, gender of the head of the household, education level of the household members and the family size.

Several studies on adoption acknowledge **age of the head** of the household as an important factor influencing the adoption decision by farmers (Feder et al., 1985; Uaiene (2011);

Teklewold et al., 2013; Ogada et al., 2014; Manda et al., 2015; Kassiet et al., 2015). One set of studies postulate a positive relationship (Meshram et al., 2012; Kassie et al., 2013) while the other set of studies postulate a negative relationship (Manda et al., 2015). Those who postulate a positive relationship argue that older farmers are more experienced and might have accumulated greater physical and social capital (Kassie et al., 2013). Nonetheless there is also belief that older farmers are less amenable to change and, therefore, unwilling to change from their old practices to new ones (Adesina and Zinnah, 1993). Some studies have found a positive relationship between age and adoption decisions (Langyintuo and Mungoma, 2008; Meshram et al., 2012). The average age of the head of the household in our sample ranges from fifty to fifty-one years. We also include a variable called **no. of years in agriculture** to capture relationship between experience in agriculture and adoption. The average years of experience in our sample ranged between twenty to twenty-four years.

Certain fixed social bias (**gender of household head**) is also expected to have an impact on technology adoption (Langyintuo and Mungoma, 2008). There is a view that women farmers face greater constraints in terms of access to resources and time and, hence, can be less enthusiastic in adoption (Pender and Gebremedhin, 2008). Manda et al. (2015) found a negative and significant relationship between the gender of the household and adoption of improved maize varieties. However Doss and Morris (2001) argue that there is no significant association between the gender of the farmer and the probability of adoption. They argue that, although, female-headed households are less likely to adopt new technologies than male headed households, this does not strictly mean that female farmers are less likely to adopt new technologies than male counterparts. Majority of the households in our sample had male head of the household.

A third important household characteristic that can have an impact on adoption decision is the **education level of the household members**. Several studies find a positive relationship between education level of the household members and adoption decisions (Moser and Barrett, 2003; Pender and Gebremedhin, 2008; Langyintuo and Mungoma, 2008; Haldar et al., 2012). The average number of an educated (education higher than 10^{th}) person in the household was one.

Another important human capital which is relevant in influencing the adoption and the extent of adoption is **number of active family labourers** (Langyintuo and Mungoma, 2008; Noltze et al., 2012). Adoption of a new technology can be less attractive to those who do not have sufficient family labourers (Langyintuo and Mungoma, 2008). Also the **household size** is used as a proxy to capture labour endowment (Pender and Gebremedhin, 2008). The number of household members had a positive and significant impact in some studies on SRI (Noltze et al., 2012). The average number of active family labourers in our sample ranged from two to three while the average number of household members was five.

We proxy the household wealth through **farm size, number of assets owned and rented** (Kassie et al., 2015). As studies show, household asset endowments play a crucial role in adoption decisions (Kassie et al., 2015). Earlier studies found a negative and significant relationship between farm size and the intensity of adoption of new technologies (Langyintuo and Mungoma, (2008; Kassie et al., 2015). However, there is also a view that farmers with larger farms will be more willing to devote portions of the land to an untried variety compared with those with smaller ones (Adesina and Zinnah, 1993). The relationship between total farm size and the adoption of new practices also depends on factors such as fixed adoption costs, risk preferences, credit constraints, labour requirements etc. (Just and Zilberman, 1983; Feder et al., 1985). Hence, the effect of farm size on the adoption of SRI is indeterminate. Majority of the farmers in our sample were marginal and small farmers with less than one hectare of land. Several studies have noted a positive relationship between the farm assets and adoption (Langyintuo and Mungoma, 2008; Kassie et al., 2015).

Agricultural extension services are an important channel for wider dissemination and adoption of technology (Langyintuo and Mungoma, 2008; Kassiet et al., 2015). The study by Devi and Ponnarasi (2009) on the adoption behaviour in Cuddalore district of Tamil Nadu showed that lack of awareness, training on new technology etc., were the determinants for adoption behaviour of farmers. Farmers' awareness of the benefits of a new technology stems from the fact that they have access to information and availability of extension services. Since SRI is a knowledge-based innovation, extension services play an even greater role in wider adoption (Noltze et al., 2012). Around 205 farmers in our sample didn't have any access to extension services. We gave a dummy variable equal to 1 for those who had access to extension services. Although SRI is not specific to any particular variety of rice, **access to seed varieties** can also play a significant role in adoption decisions in general (Langyintuo and Mungoma, 2008; Mazvimavi & Twomlow, 2009; Shiferaw et al., 2015). We also gave a dummy variable equal to 1 for those who had access to seed.

Market access also has a huge bearing on transaction cost in accessing information and technology (Kassie et al., 2015). In line with Kassie et al. (2015), we consider the **distance from main market** as a proxy for market access. The average distance for households to main market in our sample was ten to sixteen kilometres.

Several studies have pointed out that SRI is labour intensive (Senthikumar et al., 2008; Noltze et al., 2012). The reasons for poor rate of adoption and high non-adoption rates are attributed to the fact that SRI is labour intensive and requires farming skill (Barrett et al., 2004; Devi and Ponnarasi 2009; Palanisami et al., 2013). As proxy for this, our study made use of the **wage rates for male and female labourers**. The descriptive statistics show that there is a huge disparity between male and female wage rates. The male wage rate varied between Rs.147 per day to Rs.208 per day whereas the female wage rate varied between Rs.122 per day to Rs.170 per day.

Aversion to risk by farmers has also been highlighted by some studies as the reason for poor adoption (Johnson and Vijayaraghavan, 2011). To capture this, we include a variable—**fear of poor yield**—in our model. Also, it has been shown that soil type, source of irrigation etc., are important in influencing the level of adoption (Palanisami et al., 2013). In our sample, around 258 farmers (around 67%) had the fear of poor yield. We gave a dummy variable equal to 1 for those who had fear of poor yield. Proper soil management and water management are important not only in adoption but also in realising full potential of yield. Although SRI requires less water, moisture saturated but not flooded conditions require proper water management (Noltze et al., 2013). Therefore, studies have highlighted the importance of **irrigation** and irrigation management as important factors in deciding adoption of SRI (Tsujimoto et al., 2009; Noltze at al., 2012; Uphoff, 2012). Around 50% of farmers in our sample didn't have any irrigation facility. We gave a dummy variable equal to 1 for those who had irrigation facility and zero for those who did not.

Terrain type has also been found to be important in deciding adoption of SRI (Moser and Barrett, 2003). Significant differences in adoption intensity between regions have been observed (Langyintuo and Mungoma, 2008). Around 70% of the farmers did not have terrain which was levelled. We gave a dummy variable equal to one for those farmers who had terrain which is levelled and zero if otherwise. Finally, in order to capture the impact of

NFSM in promoting the adoption of SRI, we gave dummy variable equal to one for those districts where SRI is incorporated within NFSM.

Table 4.1: Descriptive Statistics of Variables used in the Analysis

Variables	All	Pack1	Pack2	Pack3	Pack4	Pack 5	Pack6	Pack7
Age of the head of the household (HOH)	50.16 (11.3)	50.41 (10.82)	50.1 (11.2)	50.8 (11.2)	50.3 (11.1)	48.9 (11.8)	50.7 (11)	50.2 (11.6)
Gender of HOH	.90 (.29)	.89 (.31)	.91 (.29)	.90 (.30)	.90 (.29)	.95 (.21)	.88 (.32)	.90 (.30)
No. of family members	5.10 (1.92)	5.20 (2.14)	5.2 (2.1)	5.4 (2.1)	5.2 (1.9)	4.8 (1.9)	5.17 (2.2)	5.3 (2.4)
Members with Education higher than 10th	.79 (1.14)	1.02 (1.17)	.86 (1.1)	.82 (1.12)	.99 (1.2)	1.06 (1.21)	1.12 (1.20)	.96 (1.18)
Number of Active family labourers	2.51 (1.26)	2.52 (1.34)	2.55 (1.29)	2.6 (1.3)	2.5 (1.3)	2.5 (1.2)	2.5 (1.4)	2.6 (1.4)
No. of years in Agriculture	24.7 (11.7)	23.0 (10.4)	23.1 (10.9)	24.7 (11.6)	23.4 (11.2)	20.3 (10.2)	23.6 (11)	24.8 (11.8)
Farm Size	.78 (.84)	.82 (.83)	.82 (.86)	.81 (.87)	.92 (.87)	1.1 (.95)	.96 (.91)	.93 (.92)
Contact with extension service, Yes=1	.47 (.50)	.60 (.49)	.58 (.49)	.56 (.50)	.59 (.49)	.56 (.50)	.70 (.46)	.70 (.46)
Membership in input supply co-operative (s), Yes=1	.40 (.49)	.53 (.50)	.49 (.50)	.52 (.50)	.48 (.50)	.42 (.50)	.60 (.49)	.61 (.49)
Distance from main market (in km)	11.48 (10.6)	12.3 (14.0)	12.3 (10.8)	12.8 (13.1)	13.1 (13.8)	17.0 (19.0)	12.8 (14.9)	10.3 (8.1)
Seed exchange experience, Yes=1	.60 (.49)	.64(.48)	.63 (.48)	.61 (.49)	.66 (.47)	.67 (.47)	.65(.48)	.57 (.50)
Wage rate for female	138.1 (59.8)	139.0 (5.4)	132.1 (46.1)	122.1 (37.7)	140.7 (54.1)	170.3 (50.7)	148.5 (59)	131.9 (46.3)
Wage rate for male	167.5 (75.5)	172.6 (74.1)	161 (65.9)	147.2 (53)	174.7 (75.4)	208.6 (83.6)	187.7 (81)	160.2 (68.7)
Fear poor yield, Yes=1	.67 (.47)	.56 (.50)	.61 (.49)	.60 (.49)	.62 (.49)	.62 (.49)	.57 (.50)	.59 (.49)

Irrigation facility, Yes=1	.50 (.50)	.62 (.49)	.62 (.49)	.65 .48)	.60 (.49)	.48 (.50)	.65 (.48)	.77 (.42)
Number of Assets owned	1.4 (1.9)	2.0 (2.5)	1.9 (2.5)	2.0 (2.5)	2.0 (2.4)	2.3 (2.9)	2.2 6(2.8)	2.1 (2.6)
Number of Assets rented	.58 (.97)	.81 (1.07)	.64 (1.0)	.45 (.78)	.76 (1.07)	1.0 (1.1)	.88 (1.12)	.65 (1.0)
Terrain type , Levelled=1	.29 (.45)	.353 (.479)	.30 (.46)	.25 (.43)	.39 (.49)	.47 (.50)	.41 (.49)	.35 (.48)
NFSM dummy	.52 (.50)	.54 (.50)	.52 (.50)	.56 (.50)	.54(.50)	.33 (.47)	.65 (.48)	.63 (.48)
No. of Observations	386	156	180	129	147	66	113	109

Note: The numbers in parenthesis are standard deviations.
Pack1: Young seedling, Pack2: Shallow planting, Pack3: Seedling, Pack4: Wider spacing, Pack5: Use of organics, Pack5: Use of cono weeder, Pack7: Wetting and drying.

4.4 Results and Discussion

The results for MVP are presented in Table 4.2. The model fits the data reasonably well—the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. As expected, the likelihood ratio test [chi2(133) = 444.53, p=0.000)] of the null hypothesis that the covariance of the error terms across equations are not correlated is also rejected.

The results showed that the assets owned by farm households is one of the most important factors determining the adoption of all SRI packages. The assets owned had a positive and significant impact on all SRI packages. Existing literature on technology adoption also highlights the significance of household assets (Langyintuo and Mungoma, 2008; Kassie et al., 2015). Another variable that came out to be statistically significant in affecting the adoption of all packages was the wage rates for female labourers. In almost all packages, the female wage rate had a negative and significant impact on adoption. The male wage rate was also significant in the adoption of three out of seven packages. But the relationship was positive. These results are similar to the ones we observed from the analysis based on multi hurdle model (see Chapter 3). As mentioned already, the weeding operations are shifting away from manual weeding to mechanical weeding, and rice farmers hire more and more of male labourers for mechanical weeding (Senthikumar et al., 2008). Therefore, the shift from manual weeding to mechanical weeding might have resulted in greater demands for male labourers and thus the positive relationship between male wage rates and SRI adoption.

Similarly, a decline in the demand for female labourers could be the reason for a negative relationship between female wage rates and SRI adoption.

Extension services, membership in farmers' organisations such as input cooperatives, irrigation facility etc., also had significant impact in affecting the adoption decisions relating to most of the packages. Existing studies on technology adoption also highlighted the importance of extension services in wider dissemination and adoption of technology (Langyintuo and Mungoma, 2008; Devi and Ponnarasi 2009; Noltze et al., 2012; Kassiet et al., 2015). Similarly, studies have highlighted the importance of irrigation in the adoption of SRI. As noted by Noltze et al. (2013), SRI necessitates proper water management. Other studies too have highlighted the importance of irrigation and irrigation management in affecting adoption decision of SRI (Tsujimoto et al., 2009; Noltze at al., 2012; Uphoff, 2012). The detailed results for SRI packages are given below.

4.4.1 Young Seedling

Membership in input supply cooperatives, wage rates, number of years in agriculture, assets owned and rented, irrigation facility etc., had significant impact on adoption of young seedlings. Assets, membership in input supply cooperatives, better irrigation facility etc., increase the likelihood of adoption. Interestingly, the experienced farmers or farmers who had been in farming for many years were less likely to adopt young seedling for rice cultivation. Similarly, fear of poor yield and female wage rates also reduced the likelihood of adoption.

4.4.2 Shallow Planting

Farmers who had been in farming for many years were less likely to adopt shallow planting as well. But the contact with extension services, membership in input supply cooperatives, number of active family labourers, better irrigation facility etc., increased the likelihood of farmers adopting shallow planting. As was the case with young seedling, the high wage rate of female labourers reduced the likelihood of farmers adopting shallow planting.

4.4.3 Seedling

Household assets, better irrigation facility, membership in input supply cooperatives etc., increased the probability for adoption of single seedlings. Wage rate for female labourers reduced the likelihood of adopting single seedling. However, the results for distance showed that distance increases the likelihood of adoption. This contradicts our hypothesis. But as mentioned earlier, majority of rice farmers were small or marginal farmers. In addition, as observed from the discussions with farmers, majority of the rice farmers cultivated rice for self-consumption and retained very little for sale in the market. Therefore, adoption of SRI by small and marginal farmers may be a strategy to improve household food security by enhancing yield. Also, SRI does not require any particular variety of seed that needs to be purchased from the market. It does not require costly innovation either. Thus, it is possible that farmers who are remotely located from the market are more attracted towards shifting to SRI than farmers who cultivate marketable crops and are close to main market. As we will see from discussions below, the distance increased the likelihood of adopting four out of seven SRI packages.

4.4.4 Wider spacing

Size of the household, contact with extension service, distance from main market, wage rate for male labourers, household assets etc., increased the likelihood of adopting wider spacing. However, the female wage rates reduced the likelihood of adoption.

4.4.5 Use of Organics

Only in the case of adoption of organics, the female wage rates increased the likelihood of adoption. Apart from this, number of years in agriculture, farm size, contact with extension services, distance from main market, education, assets owned and rented, NFSM etc., had a statistically significant impact on the use of organics. Thus, farm size, contact with extension services, distance from main market, and assets owned and rented increased the likelihood of adoption. But number of years in agriculture, education, better irrigation facility, NFSM etc., reduced the likelihood for adoption. The negative and significant relationship between NFSM dummy and adoption of organics indicate that the adoption of organics was higher in non-NFSM districts such as Chikmagalur, Sidhi and Mayurbhanj districts.

4.4.6 Use of Cono Weeder

Gender of the household head, contact with extension services, membership in input supply cooperatives, distance, wage rates, irrigation facility, assets etc., were statistically significant in the adoption of cono weeder. Extension services, membership in input supply cooperatives, male wage rates, distance, irrigation facility, assets etc., increased the likelihood for adoption, while the male head of the household, wage rate for female etc., reduced the likelihood of adoption.

4.4.7 Water Management: Wetting and Drying

Extension services, membership in input supply cooperatives, irrigation facility and assets increased the likelihood of households adopting water management, while the female wage rates reduced the likelihood for adopting water management.

Table 4.2: Result for Multivariate Probit Model

A. Young Seedling	**Coefficient**	**Z-Statistic**	**Marginal Effects**
Age of the HOH	-.002(.008)	-0.24	-.001
Gender of_HOH	-.335(.260)	-1.29	-.107
No. of family members	.029(.050)	0.57	.009
Active family labourers	.071(.069)	1.03	.023
No. of years in agriculture	-.017(.007)	-2.38**	-.005
Farm size	-.131(.108)	-1.21	-.042
Contact with extension service	.274(.187)	1.47	.088
Membership in input supply cooperatives	.440(.194)	2.27**	.141
Distance from main market	.007(.007)	0.98	.002
Seed exchange experience	.150(.149)	1.01	.048
Wage rate for male	.005(.003)	1.73*	.001
Wage rate for female	-.008(.003)	-2.36**	-.003
Fear of poor yield	-.331(.155)	-2.13**	-.106
Education higher than 10^{th}	.035(.074)	0.47	.011
Irrigation facility	.269(.158)	1.70*	.086
Terrain type	-.076(.205)	-0.37	-.024
Assets owned	.107(.033)	3.24***	.034
Assets rented	.320(.101)	3.17***	.102
NFSM	-.038(.161)	-0.23	-.012
Constant	-.124(.527)	-0.24	
B. Shallow planting			
Age of the HOH	.003(.008)	0.51	.001
Gender of HOH	-.243(.241)	-1.01	-.080
No. of family members	.032(.050)	0.64	.010
Active family labourers	.119(.068)	1.75*	.039
No. of years in agriculture	-.022(.007)	-3.13***	-.007
Farm size	.018(.099)	0.18	.006
Contact with extension service	.338(.173)	1.95**	.111
Membership in input supply cooperatives	.296(.177)	1.67*	.097
Distance from main market	.008(.006)	1.20	.002
Seed exchange experience	.145(.140)	1.04	.048
Wage rate for male	-.0002(.003)	-0.10	-.000
Wage rate for female	-.007(.003)	-2.05**	-.002
Fear of poor yield	-.083(.160)	-0.52	-.027
Education higher than 10^{th}	.012(.073)	0.16	.004

Irrigation facility	.245(.153)	1.59	.080
Terrain type	-.040(212)	-0.19	-.013
Assets owned	.132(.032)	4.15***	.043
Assets rented	.168(.117)	1.44	.055
NFSM	-.037(.151)	-0.25	-.012
Constant	.007(.513)	0.01	
C. Seedling			
Age of the HOH	.001(.008)	0.18	.004
Gender of HOH	-.297(.236)	-1.26	-.090
No. of family members	.043(.048)	0.90	.013
Active family labourers	.050(.062)	0.81	.015
No. of years in agriculture	-.005(.007)	-0.77	-.002
Farm size	.086(.096)	0.89	.026
Contact with extension service	-.038(.168)	-0.22	-.011
Membership in input supply cooperatives	.428(.172)	2.49**	.130
Distance from main market	.012(.006)	2.07**	.004
Seed exchange experience	.093(.136)	0.68	.028
Wage rate for male	.000(.002)	0.05	.000
Wage rate for female	-.007(.003)	-2.23**	-.002
Fear of poor yield	-.028(.153)	-0.18	-.008
Education more than 10th	.019(.075)	0.25	.006
Irrigation facility	.386(.143)	2.70*	.118
Terrain type	-.209(.188)	-1.11	-.064
Assets owned	.122(.30)	4.10***	.037
Assets rented	.010(.092)	0.11	.003
NFSM	-.043(.143)	-0.30	-.064
Constant	-.352(.492)	-0.72	
D. Wider spacing			
Age of the HOH	-.009(.008)	-1.16	-.003
Gender of HOH	-.321(.238)	-1.35	-.103
No. of family members	.20(.045)	2.65**	.038
Active family labourers	-.042(.060)	-0.70	-.013
No. of years in agriculture	-.010(.007)	-1.36	-.003
Farm size	.069(.096)	0.72	.022
Contact with extension service	.388(.174)	2.23**	.125
Membership in input supply cooperatives	.116(.172)	0.67	.037
Distance from main market	.018(.006)	2.79**	.006
Seed exchange experience	.196(.137)	1.43	.063
Wage rate for male	.006(.003)	2.17**	.002
Wage rate for female	-.007(.003)	-2.32**	-.002
Fear of poor yield	.089(.146)	0.61	.029
Education higher than 10th	.043(.071)	0.61	.014
Irrigation facility	.217(.141)	1.54	.069
Terrain type	.239(.192)	1.24	.077
Assets owned	.091(.029)	3.15***	.029
Assets rented	.063(.094)	1.24	.020

NFSM	-.034(.149)	-0.23	-.011
Constant	-.915(.507)	-1.81*	
E. Use of Organics			
Age of the HOH	-.007(.009)	-0.71	-.001
Gender of HOH	.032(.297)	0.11	.006
No. of family members	.037(.60)	0.63	.007
Active family labourers	.121(.077)	1.58	.021
No. of years in agriculture	-.025(.10)	-2.58**	-.004
Farm size	.372(.124)	3.00***	.066
Contact extension service	.559(.232)	2.41**	.099
Membership in input supply cooperatives	.178(.232)	0.77	.031
Distance from main market	.026(.008)	3.36***	.005
Seed exchange experience	-.165(.176)	-0.94	-.029
Wage rate for male	.002(.003)	0.07	.000
Wage rate for female	.007(.003)	1.92*	.001
Fear of poor yield	-.190(.186)	-1.02	-.034
Education higher than 10^{th}	-.179(.095)	-1.89*	-.032
Irrigation facility	-.314(.179)	-1.75*	-.055
Terrain type	-.078(.233)	-0.34	-.014
Assets owned	.184(.044)	4.23***	.033
Assets rented	.169(.102)	1.65*	.30
NFSM	-1.12(.198)	-5.64***	-.198
Constant	-1.99(.564)	-3.55***	
F. Use of Cono Weeder			
Age of the HOH	-.006(.008)	-0.75	-.002
Gender of HOH	-.597(.263)	-2.27**	-.155
No. of family members	.049(.050)	0.98	.013
Active family labourers	.034(.069)	0.50	.009
No. of years in agriculture	-.011(.007)	-1.45	-.003
Farm size	.017(.106)	0.16	.004
Contact with extension service	.638(.185)	3.45***	.166
Membership in input supply cooperatives	.329(.190)	1.74*	.086
Distance from main market	.016(.007)	2.22**	.004
Seed exchange experience	.185(.154)	1.20	.048
Wage rate for male	.010(.003)	3.63***	.003
Wage rate for female	-.009(.003)	-2.72**	-.002
Fear of poor yield	-.148(.159)	-0.93	-.038
Education higher than 10^{th}	.037(.076)	0.49	.010
Irrigation facility	.355(.159)	2.23**	.092
Terrain type	-.027(.200)	-0.14	-.007
Assets owned	.114(.031)	3.64***	.030
Assets rented	.071(.094)	0.75	.018
NFSM	.176(.162)	1.08	.046
Constant	-1.52(.534)	-2.84**	
G. Wetting and drying			
Age of the HOH	-.010(.008)	-1.29	-.003

Gender of HOH	-.335(.252)	-1.33	-.089
No. of family members	.044(.051)	0.87	.012
Active family labourers	.045(.070)	0.64	.012
No. of years in agriculture	-.004(.007)	-0.55	-.001
Farm size	.110(.105)	1.05	.029
Contact with extension service	.367(.187)	1.96**	.097
Membership in input supply cooperatives	.395(.183)	2.15**	.105
Distance from main market	-.004(.007)	-0.64	-.001
Seed exchange experience	-.068(.152)	-0.45	-.018
Wage rate for male	.002(.003)	0.92	.001
Wage rate for female	-.006(.003)	-1.78*	-.002
Fear of poor yield	.020(.164)	0.12	.005
Education higher than 10^{th}	.016(.077)	0.21	.004
Irrigation facility	.797(.161)	4.93***	.212
Terrain type	-.168(.208)	-0.81	-.045
Assets owned	.098(.031)	3.11***	.026
Assets rented	.108(.091)	1.19	.029
NFSM	-.018(.154)	-0.12	-.005
Constant	-.657(.499)	-1.32	
No of observations	386	LR chi2(133)	444.53
Log likelihood	-830.9743	Prob>chi2	0.000

Note: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard errors are in parentheses

The results for ordered probit model are presented in Table 4.3. Although the magnitude of coefficients is slightly different, the same variables were significant in both models. The chi-squared statistic for the ordered probit model is 92.62 and is statistically significant, indicating that the joint test of all slope coefficients equal to zero is rejected. Results reveal that the number of SRI packages adopted increases with extension services, membership in input supply cooperatives, wage rates for male labourers, distance from main market, better irrigation facility, assets owned and rented etc. But the female wage rate and number of years in agriculture reduced the likelihood of households adopting SRI packages. These were the variables that came out to be significant in the MVP model as well. Although the present study hypothesised a significant impact of NFSM in adoption of SRI packages, the results proved otherwise. The results for NFSM were not only insignificant but in most cases turned out to be negative.

4.5. Conclusions and Implications

In this chapter we analysed the probability and level of adoption of multiple packages of SRI by rice farmers of selected regions in India using household level data. SRI is a package of components and partial adoption is commonplace. Therefore, it is crucial to understand why farmers adopt only some but not all modified practices. We used MVP and ordered probit models to jointly analyse the adoption of multiple packages and the number of SRI packages adopted while recognising the interrelationship among them. Our approach extends the existing empirical studies by allowing for correlations across different packages of SRI. Since existing studies have highlighted significant yield differences between partial and full adoption of packages, it is very crucial to get an insight into why farmers adopt or do not adopt certain packages (Palanisami et al., 2013). The districts that we identified had one of the highest gross income and yield difference between traditional and SRI cultivation (Palanisami et al., 2013). Therefore, from a policy perspective, understanding the determinants of SRI adoption could help design region-specific strategies. The empirical results show that various economic, institutional and access-related factors shape smallholders' adoption of SRI packages.

The adoption of agricultural technologies in developing countries is mostly connected to farmers' economic ability to access new technologies. The importance of households' assets in influencing the adoption decisions have been well documented in the literature (Awotide et al., 2012; Kassie et al., 2015). The present study found a significant and positive relationship between households' assets and adoption of SRI packages. Another very important revelation from our study is how certain fixed social bias and gender disparities are affecting the adoption. Despite considerable disparities in wage rates between male and female labourers, the analysis showed that female wage rates reduced the likelihood of adoption of almost all packages. Interestingly, the male wage rate generally increased the likelihood of adoption. The weeding operations under conventional rice cultivation have been traditionally done by women. However as a result of SRI adoption, rice farmers hire more and more of male labourers for mechanical weeding (Senthikumar et al., 2008). The shift from manual weeding to mechanical weeding resulted in greater demand for male labourers and this could be the reason for a positive relationship between male wage rates and SRI adoption. The results also highlight the skill-intensive nature of SRI adoption and the gender implications of SRI adoption.

Information and extension services are very important driving-forces for enhancing adoption of SRI. Knowledge and awareness are particularly relevant for innovations such as SRI where the adoption is more from sustainability perspective than immediate benefits (Noltze at al., 2012). Our results showed the importance of extension services in influencing adoption decisions. The insignificant impact of NFSM districts dummy on SRI adoption is an eloquent testimony to the fact that the objective of increased rice production by promoting SRI under the Government’s food security mission did not yield the desired results. Additionally, most farmers who had been in farming for several years did not get attracted to new methods. Also, farmers who are remotely located from the main market had higher likelihood of adopting SRI. This also indicates the possibility of cultivation of commercial crops by those farmers who were located close to the market. Most farmers we interviewed did not consider rice farming as a commercially-viable venture; instead, the production was mainly for self-consumption and sale in the local markets.

The study also pointed out the importance of investment in infrastructure such as irrigation in promoting SRI. Although SRI requires less water as compared to the traditional method, farmers need their own irrigation facility to meet the requirement of proper water management which is an essential component of SRI.

The significance of social capital and networks were also observed in our analysis. The membership in farmers’ organisations such as input supply cooperatives increased the likelihood of SRI adoption. The significance of these factors indicates that policy makers should focus on establishing and strengthening local collective institutions. Local institutions can play a crucial role in providing farmers with timely information, inputs and technical assistance.

Table 4.3: Ordered Probit Estimation for Total Packages

Variables	Coefficient	Marginal Effects							
		P(Y=0/X)	P(Y=1/X)	P(Y=2/X)	P(Y=3/X)	P(Y=4/X)	P(Y=5/X)	P(Y=6/X)	P(Y=7/X)
Age of the HOH	-.005(.007)	.002	.000	-.000	-.0001	-.0003	-.001	-.001	-.0002
Gender of HOH	-.192(.209)	.076	.0001	.0002	-.002	-.010	-.024	-.031	-.009
No. of family members	.032(.041)	-.013	-.000	.00003	.001	.002	.004	.005	.001
Active family labourers	.063(.058)	-.025	-.000	.0001	-.001	.004	.008	.010	.002
No. of years in agriculture	-.013(.006)**	.006**	.000	-.000	-.0002*	-.001**	-.002**	-.002**	-.005**
Farm size	.051(.086)	-.020	-.000	.000	.001	.003	.006	.008	.002
Contact with extension service	.429(.156)**	-.170***	-.000	.0002	.006*	.025**	.054**	.066**	.017**
Membership in input supply cooperatives	.301(.157)**	-.119**	-.000	.000	.004*	.017**	.038**	.047*	.012*
Distance from main market	.009(.005)*	-.004*	-.000	.000	.000	.001*	.001*	.001*	.0003
Seed exchange experience	.091(.125)	-.036	.000	.000	.001	.006	.012	.014	.003
Wage rate for male	.004(.002)*	-.001*	-.000	.000	.0001	.0002	.0004*	.001*	.0001
Wage rate for female	-.005(.003)**	.002**	.000	-.000	-.000	-.0003*	-.001**	-.001**	-.0002*
Fear of poor yield	-.186(.132)	.074	.000	-.000	-.003	-.011	-.024	-.029	-.008
Education higher than 10^{th}	.035(.060)	-.014	-.000	.000	.001	.002	.004	.005	.001

Irrigation facility	.357(.127)**	-.141**	.000	.000	.006*	.021**	.045**	.054**	.014**
Assets owned	.114(.029)***	-.046***	-.000	.000	.002**	.007***	.015***	.017***	.004**
Assets rented	.128(.074)*	-.051*	-.000	.000	.002	.007*	.016*	.019*	.005
Terrain type	-.037(.168)	.015	-.000	-.000	-.001	-.002	-.005	-.005	-.001
NFSM	-.070(.132)	.028	.000	-.0001	-.001	-.004	-.009	-.011	-.003
μ1	.177(.430)								
μ2	.192(.431)								
μ3	.253(.431)								
μ4	.485(.432)								
μ5	.847(.433)**								
μ6	1.40(.434)***								
μ7	2.35(.448)***								
No. of observations	386	LR chi2(19)	92.62						
Log Likelihood	-543.7542	Prob> chi2	0.000						

Note: ***, **, and * denote statistical significance at the 10%, 5%, and 1% levels respectively. Standard errors are in parentheses

Chapter 5
Impact of SRI Adoption on Yield and Household Income

5.1 Introduction

Although there have been studies analysing the adoption and impact of SRI on household income and yield, there are hardly any studies analysing the factors that affect the decisions to adopt individual as well as the combinations of SRI principles and their impact using a multinomial selection framework. Therefore, this paper contributes to the literature on SRI by identifying various factors that affect the decisions to adopt major principles of SRI—plant management, soil management and water management—as well as the combination of these principles and their impact on yield and income. The modelling technique adopted is a multinomial selection process where the expected benefits of SRI induce the adoption decisions (Manda et al., 2015). The study makes use of the multinomial endogenous treatment effects model (Deb and Trivedi, 2006b) to account for selection bias due to both observed and unobserved heterogeneity and to assess the differential impacts of the adoption of different combinations of SRI. The multinomial endogenous treatment effects model allows the modelling of interdependency among the different components (Manda et al., 2015). Multinomial endogenous treatment effects model allows the distribution of the endogenous treatment (adoption of SRI) and outcomes (income and yield) to be specified using a latent factor structure, thereby allowing a distinction to be made between selection on observable and unobservable characteristics (Deb and Trivedi, 2006b).

The remainder of the chapter is organised as follows. Section 5.2 discusses the variables and hypothesis used in the analysis. Section 5.3 describes conceptual framework and the multinomial endogenous treatment effects model, followed by section 5.4 which presents the empirical results. The last section provides conclusion.

5.2 Description of Variables and Hypothesis

Several studies have included household characteristics such as **age of the head** of the household, gender of the head of the household, size of the household, education etc., as important factors influencing the adoption decision by farmers (Feder et al., 1985; Uaiene, 2011; Teklewold et al., 2013; Ogada et al., 2014; Manda et al., 2015). As far as the age is concerned, one set of studies postulate a positive relationship (Meshram et al., 2012; Kassie et al., 2013) and the other set of studies a negative relationship (Manda et al., 2015). Those who postulate a positive relationship argue that older farmers are more experienced and might have accumulated greater physical and social capital (Kassie et al., 2013). Nonetheless, there is also a belief that older farmers are less amenable to change and, therefore, unwilling to change from their old practices to new ones (Adesina and Zinnah, 1993). There exist studies that have found a positive relationship between age and adoption decisions (Langyintuo and Mungoma, 2008; Meshram et al., 2012). **Education of the household** is also expected to have a positive impact on adoption decisions (Moser and Barrett, 2003; Pender and Gebremedhin, 2008; Langyintuo and Mungoma, 2008). Therefore, both age and education is expected to have a significant impact on the adoption decision (Meshram et al., 2012). The study by Haldar et al (2012) for the Bardhaman district in West Bengal also showed that education level is important in adopting SRI.

Another human capital which is relevant in influencing the adoption and the extent of adoption is **number of active family labourers** (Langyintuo and Mungoma, 2008; Noltze et al., 2012). Adoption of a new technology can be less attractive to those who do not have sufficient family labourers (Langyintuo and Mungoma, 2008). Also the **household size** is used as a proxy to capture labour endowment (Pender and Gebremedhin, 2008). The number of household members had a positive and significant impact in some studies on SRI (Noltze et al., 2012). Apart from all these, certain fixed social bias (**gender of household head**) is also expected to have an impact on adoption (Langyintuo and Mungoma, 2008). There is a view that women farmers face greater constraints in terms of access to resources and time and, hence, can be less enthusiastic in adoption (Pender and Gebremedhin, 2008). Manda et al. (2015) found a negative and significant relationship between the gender of the household and adoption of improved maize varieties. However, Doss and Morris (2001) argue that there is no significant association between the gender of the farmer and the probability of adoption. They argue that, although, female-headed households are less likely to adopt new technologies than male-headed households, this does not strictly mean that female farmers are less likely to adopt new technologies than male counterparts.

The **total farm size** is also important in the adoption decisions. Langyintuo and Mungoma (2008) found a negative and significant relationship between farm size and the intensity of adoption of improved maize varieties in Zambia. However, in the case of SRI, although it is recognized as a promising systemic approach to increase rice production at affordable costs for small-scale producers, studies postulate a positive relationship between farm size and the adoption. This is due to the fact that farmers with larger farms will be more willing to devote portions of the land to an untried variety compared with those with smaller ones (Adesina and Zinnah, 1993). The relationship between total farm size and the adoption of new practices also depends on factors such as fixed adoption costs, risk preferences, credit constraints, labour requirements etc. (Just and Zilberman, 1983; Feder et al., 1985). Hence, the effect of farm size on the adoption of SRI is indeterminate.

Apart from the size of the farm, the **assets owned** by the farmer is also important in deciding the adoption (Langyintuo and Mungoma, 2008). The households' ability to cope with production and price risk increases with an increase in wealth or stock of productive assets. Also, we consider the impact of farmers who have **farming as main occupation** on adoption decisions. The study by Noltze et al., (2013) showed that household heads whose main occupation is farming are much less likely to adopt SRI.

Access to off-farm activities and income in general is expected to have a positive impact on adoption decisions (Davis et al., 2009). The study by Langyintuo and Mungoma (2008) found a positive relationship in the case of adoption of improved maize varieties, and the study by Noltze et al. (2012) found a positive relationship in the case of SRI adoption. However, the studies by Mathenge et al. (2015) and Manda et al. (2015) found a negative relationship between the two.

Another factor which is very crucial for adoption especially in the context of SRI is the **availability of labourers**. Studies find SRI to be very labour intensive (Senthikumar et al., 2008; Noltze et al., 2012). It has been argued that the reasons for poor rate of adoption and high non-adoption rates are due to the fact that SRI is labour intensive and requires farming skill (Barrett et al., 2004; Palanisami et al., 2013). The study by Devi and Ponnarasi (2009) on the adoption behaviour in Cuddalore district of Tamil Nadu showed that lack of skilled labourers, awareness, training on new technology, farm income, experience etc., were the determinants for adoption behaviour of farmers. Farmer's awareness of the benefits of a new technology stems from the fact that they have **access to information and extension services**. Since SRI is a knowledge-based innovation, extension services play an even greater role in wider adoption (Noltze et al., 2012). In order to make the information available to farmers in an effective manner regular visits to the field and guidance are very important (Langyintuo and Mungoma, 2008). There are studies that point out the importance of access to information, **access to seed, access to credit** etc., in determining the adoption decision even for a farmer with positive demand for adoption (Langyintuo and Mungoma, 2008; Mazvimavi & Twomlow, 2009; Shiferaw et al., 2015). Participation in training programmes was found to have a positive impact on SRI adoption in Timor Leste (Noltze et al., 2012). Similarly, Moser and Barrett (2003) found a positive relationship between information availability and SRI adoption in Madagascar.

Aversion to risk by farmers has also been highlighted by some studies as the reason for poor adoption (Johnson and Vijayaraghavan, 2011). To capture this, we include a variable **fear of poor yield** in our model. Also, literature shows that soil type, source of irrigation etc., are important in influencing the level of adoption (Palanisami et al., 2013). Proper soil management and water management are important not only in adoption but also in realising full potential of yield. Although, SRI requires less water, moisture saturated but not flooded conditions require proper water management (Noltze et al., 2013). Therefore, studies have highlighted **irrigation** and irrigation management as important factors in deciding adoption of SRI (Tsujimoto et al., 2009; Noltze at al., 2012; Uphoff, 2012).

Terrain type is also found to be important in deciding adoption of SRI (Moser and Barrett, 2003). Significant differences in adoption intensity between regions have been noticed (Langyintuo and Mungoma, 2008). Also there are studies on technology adoption that capture the differences in regions through **district dummies.** Therefore, in our analysis we include district dummies to capture the differences in adoption across various regions.

5.3 Conceptual and Econometric Framework

Adoption of agricultural technologies is not a simple yes or no decision. The technologies are usually introduced in packages that include several components. Farmers often choose only parts of a technology package or apply combination of practices only on small parts of their cultivated area (Smale, Heisey, & Leathers, 1995). Therefore, an adoption decision is inherently multivariate. Attempting univariate modelling would exclude useful economic information about interdependent and simultaneous adoption decisions (Dorfman, 1996). Farmers tend to adopt mix of components from an agricultural technology package to deal with a multitude of agricultural production constraints. In most cases, the different components may complement each other (Feder et al., 1985). There have been many attempts to model the interrelationship in the adoption of multiple agricultural technologies, of which Feder's (1982) was one of the pioneering attempts. In recent years, more studies have looked at the joint estimation of multiple agricultural technologies (Teklewold et al., 2013; Manda et al., 2015). The study by Teklewold et al. (2013) utilised multivariate and ordered probit models to the modelling of adoption decisions by farm households. Based on a random utility framework, a multinomial endogenous treatment effects model was applied by Manda et al. (2015).

In line with Manda et al. (2015), the present study makes use of a multinomial endogenous treatment effects model proposed by Deb and Trivedi (2006a,b). We consider the adoption of SRI as a choice over 5 combinations comprising three major principles such as soil management, plant management, and water management.[5]

Farmers will adopt a practice or a combination of practices that can provide maximum utility to them subject to various constraints. In order to maximise the utility U_{ij} farmer will compare alternative practices and combinations. Accordingly, an i^{th} farmer will choose a practice j, over any alternative practice, k, if $U_{ij}>U_{ik}$, $k\neq j$.

As farmers may endogenously self-select adoption or non-adoption, decisions are likely to be influenced systematically both by observed and unobservable characteristics that may be correlated with the outcomes of interest. To disentangle the pure effects of adoption and to effectively asses the adoption and impact of SRI, we adopt a multinomial endogenous treatment effects model proposed by Deb and Trivedi (2006b). This approach has the advantage of evaluating both individual and combined practices, while capturing the interactions between the choices of alternative practices (Wu and Babcock, 1998; Mansur et al., 2008).

[5] **Soil management**: The use of organic matter to improve soil quality and performing weeding using a mechanical rotary weeder. **Plant management**: Planting single young seedlings (between 8-12 days old) carefully, gently and horizontally into the soil with wider spacing. **Water management**: Keeping the soil moist but not continuously flooded during the plants' vegetative growth phase, until the stage of flowering and grain production.

5.3.1 Model Specification

The multinomial endogenous treatment effects model consists of two stages. In the first stage of the model, a farmer will choose one of the three practices mentioned above. Following Deb and Trivedi (2006a,b), let U_{ij} denote the indirect utility associated with the j^{th} SRI practice, j = 0, 1, 2, ..., J for farmer i:

$$U_{ij}^{*} = Z_i^{\prime}\alpha_j + \sum_{k=1}^{j}\delta_{jk}l_{ik} + n_{ij} \qquad (1)$$

Where z_i denotes the vector of household, social, economic and institutional factors associated parameters α_j; η_{ij} are independently and identically distributed error terms. Also U_{ij}^{*} includes a latent factor l_{ik} that incorporates unobserved characteristics common to famer i's treatment choice and outcome variables. Outcome variables in our analysis are plant, soil, and water management practices whereas the unobserved characteristics that may have an impact on outcome variables are management and technical abilities of farmers in understanding new practices and other infrastructural and institutional constraints (Manda et al., 2015). The l_{ik} are assumed to be independent of n_{ij}. Following Deba and Trivedi (2006b), let j=0 denote the control group and $U_{I0}^{*} = 0$. The control group in our analysis are the non-adopters of SRI. Let d_j be the observable binary variables representing the choice of various practices and as a vector of d_i = (di1, di2, ..., diJ). Similarly, let $l_i = (l_{i1}, l_{i2}, ..., l_{iJ})$. Then the probability of treatment can be represented as:

$$\text{pr}(d_i \mid z_i l_i) = g(z_i^{\prime}\alpha_1 + \delta_1 l_{i1,}\, z_i^{\prime}\alpha_2 + \delta_2 l_{i2} \,\ldots\ldots\ldots\, z_i^{\prime}\alpha_j + \delta_j l_{ij} \qquad (2)$$

Where g is an appropriate multinomial probability distribution. Following Deb and Trivedi (2006b), we assume that g has a mixed multinomial logit (MMNL) structure, defined as:

$$\Pr(d_i \mid z_i l_i) = \frac{\exp(z_i^{\prime}\alpha_j + \delta_j l_{ij})}{1 + \sum_{k=1}^{j}\exp(z_i^{\prime}\alpha_k + \delta_k l_{ik})} \qquad (3)$$

The analysis of the impact of adoption of SRI on household income and rice yield is undertaken in the second stage. The expected outcome equation can be defined as:

$$E(y_i|d_i x_i l_i) = x_i'\beta + \sum_{j=1}^{j} \Upsilon_j d_{ij} + \sum_{j=1}^{j} \lambda_j l_{ij} \quad (4)$$

Where y_i represents the outcome variables—household income and rice yield for farmer i, whereas x_i is a set of exogenous covariates with associated parameter vectors β, and γ_j denotes the treatment effects relative to the control group i.e., non-adopters of SRI. The possible endogeneity in adoption decision of SRI would lead to inconsistent estimates Υ as we treat d_{ij} to be exogenous (Manda et al., 2015). The $E(y_i|d_i, x_i, l_i)$ is a function of each of the latent factors l_{ij}. This shows the outcome is affected by unobserved characteristics that also affect selection into treatment. When λ_j, the factor-loading parameter, is positive (negative), treatment and outcome are positively (negatively) correlated through unobserved characteristics. This implies that there is positive (negative) selection, with γ and λ the associated parameter vectors respectively. In line with Manda et al. (2015), we assume a normal distribution function as in our case the outcome variables—household income and yield—are continuous variables. The model was estimated with the Maximum Simulated Likelihood (MSL) method using the stata command *mtreatreg*, and 200 simulation draws.

Next step is of including valid instruments in the model. As per Deb and Trivedi (2006a) the parameters of the model are estimated even if the explanatory variables in the treatment equation is the same as the ones used in the outcome equation; the use of exclusion restrictions or instruments will provide more robust estimates. In our analysis, therefore, we include additional variables in the treatment equation that are not correlated with outcome variables. We use availability of sources of information regarding SRI as our instrument variable. The information regarding SRI can have an impact on the adoption decisions of SRI but will hardly influence the outcomes such as farmers' income and rice yield. Several studies on adoption and impacts of technology have utilised information as an instrument variable (Di Falco and Bulte, 2011; Di Falco and Veronesi, 2013; Manda et al., 2015). In line with Manda et al. (2015), we ran a test to see the validity of instruments and these results are presented in Table 5.2. The instrument variables that we selected have an impact on the adoption decision by farmers in most cases, but do not have any impact on the outcome variables among non-adopters.

5.4 Estimation Results and Discussion

5.4.1 Descriptive Statistics

Descriptive statistics of the explanatory variables that are hypothesised to influence adoption as well as outcome variables—yield and income—are presented in Table 5.1. The stata command *egen (plant management soil management water management)* produced mutually exclusive combinations of five groups. The first group was non-adopters which had 193 households. The total number of adopters was 193. Among the adopters, around 89 households (46%) had adopted all three components of SRI. Plant management and soil management was adopted by around 47 farmers (24%). Similarly, for plant management alone there were 38 households (20%), and for plant management and water management alone there were 19 households (10%).

Table 5.1: Descriptive Statistics of Variables used in the Model

Variable	Non-adoption of SRI	Plant management	Plant management and water management	Plant management and soil management	Plant management, soil management and water management
Gender of HOH (male=1)	.906(.291)	.894(.311)	.894(.315)	.914(.282)	.898(.303)
No. of family members	4.97(1.77)	5.60(1.58)	5.36(2.29)	4.76(1.41)	5.28(2.43)
No. of educated members (higher than 10th)	.683(1.13)	.631(1.12)	1.05(1.22)	.936(1.05)	.955(1.18)
Active family labourers (in no.)	2.48(1.22)	2.63(1.26)	2.68(1.33)	2.27(1.01)	2.60(1.45)
Size of landholding	3.04(2.66)	2.30(1.64)	4.14(5.22)	3.31(1.87)	3.87(3.24)
Access to off-farm activity (Yes=1)	.383(.498)	.263(.446)	.210(.418)	.361(.485)	.224(.419)
Farming is main occupation (Yes=1)	.725(.447)	.815(.392)	.894(.315)	.787(.413)	.910(.287)
Contact with extension service (Yes=1)	.367(.483)	.394(.495)	.526(.512)	.425(.499)	.730(.446)
Fear of poor yield (Yes=1)	.725(.447)	.684(.471)	.684(.477)	.617(.491)	.561(.498)
Terrain type	.259(.439)	.210(.474)	.315(.477)	.404(.496)	.370(.508)

Irrigation facility	.404(.492)	.473(.506)	.631(.495)	.297(.462)	.808(.395)
Assets owned	.974(.717)	1.39(1.82)	2.10(2.60)	2.31(3.00)	2.08(2.59)
Asset rent received per day	177.72(291.8)	159.2(295.4)	228.9(339.24)	342.5(297.8)	225.8(305.3
Difficulty in getting labourers (Yes=1)	.492(.501)	.368(.488)	.421(.507)	.404(.496)	.483(.502)
Other crops cultivated (Yes=1)	.419(.494)	.289(.459)	.421(.507)	.276(.452)	.224(.419)
Sources of Information about SRI	1.59(1.06)	1.89(.508)	1.57(.692)	1.57(.499)	1.42(.541)
Seed exchange experience (Yes=1)	.569(.496)	.684(.471)	.473(.512)	.744(.440)	.595(.493)
Chikmagalur District (Karnataka)	.103(.305)	0(0)	0(0)	.191(.397)	.123(.330)
Shahdol District (Madhya Pradesh)	.155(.363)	.078(.273)	.421(.507)	0(0)	.213(.412)
Sidhi District (Madhya Pradesh)	.165(.372)	.289(.459)	0(0)	.255(.440)	.101(.303)
Keonjhar District (Orissa)	.253(.436)	.210(.413)	.315(.477)	.170(.379)	.303(.462)
Mayurbhanj (Orissa)	.212(.410)	.421(.500)	.263(.452)	.106(.311)	.168(.376)
No. of Observations	193	38	19	47	89

Note: Standard deviations are in parentheses.

5.2: Parameter Estimates: Test on Validity of Selection Instruments

Variables	Ln Rice yields/ha	Ln Household income
Gender of HOH (male=1)	.023(.050)	.110(.044)**
No. of family members	-.002(.013)	-.013(.009)
No. of educated members (higher than 10^{th})	-.010(.013)	.014(.014)
Active family labourers (in no.)	.011(.016)	.009(.013)
Size of landholding	-.009(.007)	.046(.012)***
Access to off-farm activity (Yes=1)	.122(.053)**	-.002(.049)
Farming is main occupation (Yes=1)	.097(.058)*	-.008(.054)
Contact with extension service (Yes=1)	.108(.040)**	.003(.036)
Fear of poor yield (Yes=1)	-.044(.043)	-.067(.033)**
Terrain type	.061(.060)	.092(.041)**
Irrigation facility	.015(.040)	.041(.033)
Assets owned	.027(.020)	.056(.014)***
Asset rent received per day	.0001(.0001)**	.0001(.0001)**

Difficulty in getting labourers (Yes=1)	.038(.036)	.0003(.033)
Other crops cultivated (Yes=1)	.050(.038)	.034(.032)
Information about SRI (Yes=1)	-.000(.016)	.001(.015)
Seed exchange experience (Yes=1)	.000(.037)	-.039(.029)
Chikmagalur District (Karnataka)	.190(.057)***	.020(.071)
Shahdol District (Madhya Pradesh)	-.234(.065)***	-.214(.067)***
Sidhi District (Madhya Pradesh)	-.503(.077)***	-.267(.071)***
Keonjhar District (Orissa)	-.0002(.059)	-.231(.073)***
Mayurbhanj (Orissa)	-.178(.060)***	-.267(.062)***
Constant	.832(.126)***	-.409(.102)***
No. of Observations	193	193

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

5.4.2 Factors Influencing the Adoption of SRI

Table 5.2 presents parameter estimates of the mixed multinomial logit model which is equivalent to the first stage of our multinomial endogenous treatment effects model. The base category is non-adoption against which results are compared. The model fits the data very well with the Wald test, chi2 = *14290*, P > chi2 = 0.000 implying that the null hypothesis that all the regression coefficients are jointly equal to zero is rejected.

The results show that adoption of most packages increases with the assets owned by households and it was significant and positive for all combinations. Similarly, greater extension services had a positive impact on the adoption in most cases. This is consistent with some studies on technology adoption in general (Adegbola and Gardebroek, 2007; Manda et al., 2015) as well as in the specific context of SRI (Noltze et al., 2012). However, farm size generally had a negative impact and was significant in terms of the adoption of plant management indicating greater adoption of SRI by smaller farms. This is in contrast with findings of Noltze et al. (2012) in the study on SRI in Timor Leste. Those households which had farming as main occupation were adopting all combinations of SRI and the relationship between the variables was significant and positive. Fear of poor yield from rice as well as the cultivation of other crops by households reduced the adoption of SRI in most cases. Better irrigation facility was crucial only for the full adoption of SRI. However, it was significant and negative for plant and soil management indicating that those who have adopted the combination of plant and soil management alone didn’t adopt the water management. The main instrument variable utilised in our model—information regarding SRI—showed the positive impact of greater information on the adoption of initial combinations such as plant management, and plant management plus water management. This is an indication of the importance of information in the initial adoption decisions rather than in the intensity of adoption. This is consistent with the recent studies on technology adoption behaviour (Manda et al., 2015). As far as the district dummies are concerned, compared to Chikmagalur district, the adoption of all combinations was significantly lower in the other district of Karnataka. However, the adoption of plant management was significantly higher in the four districts of other two States than in Chikmagalur. This indicates higher initial adoption of SRI in the other two States as compared to Karnataka. In addition, plant and water management was significantly higher in Orissa and Shahdol district of Madhya Pradesh. Plant and soil management was significantly lower in Hassan district as well as in the districts of the other two States as compared to Chikmagalur. Although the district analysis reveals wider adoption of SRI in other districts as compared to the relatively developed district of Chikmagalur, the relatively low level of adoption in terms of all packages of SRI indicates inherent infrastructure bottlenecks faced by States like Orissa and Madhya Pradesh.

Table 5.3: Mixed Multinomial Logit Model Estimates of Adoption of SRI (Baseline Category is Non-Adoption of SRI)

Variable	Plant Management	Plant management and water management	Plant management and soil management	Plant management, soil management and water management
Gender of HOH (male=1)	.394(.753)	-.202(.947)	-.089(.717)	-.343(.551)
No. of family members	.206(.151)	-.079(.162)	.250(.171)	.037(.111)
No. of educated members (higher than 10th)	-.162(.255)	.192(.219)	-.316(.246)	-.087(.176)
Active family labourers	.031(.233)	.144(.198)	-.402(.242)*	.091(.151)
Size of landholding	-.390(.194)**	.003(.076)	-.087(.094)	-.058(.065)
Access to off-farm activity (Yes=1)	-.911(.754)	-.163(1.01)	-.098(.671)	.207(.507)
Farming is main occupation (Yes=1)	-.440(.891)	.998(1.14)	.436(.754)	1.25(.699)*
Contact with extension service (Yes=1)	.404(.499)*	-.172(.595)	.669(.530)	1.76(.431)***
Fear of poor yield (Yes=1)	-.234(.494)	.092(.541)	-.823(.512)*	-.800(.377)**

Terrain type	1.16(.646)*	.321(.597)	.287(.680)	.127(.522)
Irrigation facility	.157(.485)	.854(.676)	-1.19(.512)**	1.66(.395)***
Assets owned	.403(.232)*	.515(.205)**	.625(.168)***	.506(.175)**
Asset rent received per day	.0002(.001)	.001(.001)	.001(.001)	.001(.001)
Difficulty in getting labourers (Yes=1)	-.716(.483)	-.784(.637)	-.715(.507)	-.542(.401)
Other crops cultivated (Yes=1)	-.862(.474)*	.451(.686)	-.889(.514)*	-.751(.417)*
Information about SRI (Yes=1)	.575(.225)**	.448(1.57)**	-.337(.204)*	-.024(.203)
Seed exchange experience (Yes=1)	.510(.443)	-.528(.572)	.711(.506)	.084(.386)
Chikmagalur District (Karnataka)	-20.2(1.49)***	-19.8(2.06)***	-1.25(.732)*	-.402(.764)
Shahdol District (Madhya Pradesh)	19.10(1.69)***	22.20(1.93)***	-42.04(.864)***	-.038(.818)
Sidhi District (Madhya Pradesh)	20.16(1.52)***	-18.9(1.89)***	-1.12(.918)	.143(.944)
Keonjhar District (Orissa)	19.83(1.49)***	21.1(1.89)***	-2.37(.831)***	-.149(.834)
Mayurbhanj (Orissa)	20.79(1.40)***	20.83(2.02)***	-2.59(.940)***	-.160(.779)
Constant	0.000(0.00)	0.00(0.00)	.195(1.44)	-3.71(1.39)**
Wald chi2=14290, P>chi2=0.0000				

Note: Sample size is 386 and 200 simulation draws were used. ***P < 0.01, **P < 0.05, *P < 0.1. Robust standard errors are in parentheses.

5.4.3 Average Treatment Effects of Single as well as Different Combinations of SRI

Table 5.4 presents the estimates of the impact of SRI combinations on rice yield and household income. For comparison purposes, the outcome variables are estimated under the assumptions of exogenous and endogenous adoption decisions. The results under the assumption of exogenous adoption showed that adopters had higher yield compared to non-adopters, and the results were statistically significant for all combinations of SRI. The results for income, however, were interestingly different. Although, all combination had a statistically significant impact on household income, the combinations such as plant management, and plant plus soil management had a negative impact on income probably indicating higher expenses incurred in adopting these packages. Nonetheless, inferences on the assumption of exogenous SRI may be misleading as it ignores the effects of unobserved factors (Manda et al., 2015).[6] Therefore, in line with Manda et al. (2015) a multinomial endogenous treatment effects model is estimated to overcome this problem.

The average adoption effects after controlling for unobserved heterogeneity show similar results in terms of yield but a different picture in terms of income. All combinations of SRI had a positive and significant impact on rice yield as compared to non-adopters whereas the impact on income was evident only in the case of full adoption of SRI. Interestingly, none of the household characteristics were significant in affecting the yield, whereas in general, the gender of the head of the household (higher income if the head of the household is male), education of household, and size of land holding contributed significantly to household income. District dummies were significant in almost all cases indicating lower yield and income realisation from the districts of Madhya Pradesh and Orissa as compared to the districts of Karnataka. The results indicate inherent differences in development across these States despite greater adoption of SRI in Orissa and Madhya Pradesh as compared to Karnataka.

Table 5.4: Multinomial Endogenous Treatment Effects Model Estimates of SRI Impacts on Household Income and Rice Yield

SRI practice	Rice yield	Household income
Exogenous		
Plant Management	.229(.049)***	-.085(.004)***
Plant Management and Water Management	.353(.065)***	.073(.006)***
Plant Management and Soil Management	.165(.058)**	-.083(.004)***
Plant Management, Water Management and Soil Management	.392(.033)***	.115(.007)***
Gender of HoH (male=1)	-.035(.036)	.179(.005)***
No. of family members	.007(.009)	.013(.001)***
No. of educated members (higher than 10th)	-.035(.036)	.020(.001)***
Size of landholding	-.006(.005)	.039(.001)***
Active family labourers	.015(.011)	-.010(.001)***
Assets owned	-.003(.007)	.001(.001)
Access to off-farm activity	.034(.029)	.002(.004)**
Chikmagalur District	.103(.041)**	.016(.008)**

[6] The difference in welfare outcomes could be caused by unobservable characteristics of the farm households, such as their management abilities (Abdulai and Huffman, 2014; Manda et al., 2015).

(Karnataka)		
Shahdol District (Madhya Pradesh)	-.268(.051)***	-.308(.010)***
Sidhi District (Madhya Pradesh)	-.632(.052)***	-.342(.007)***
Keonjhar District (Orissa)	-.150(.046)***	-.315(.009)***
Mayurbhanj (Orissa)	-.334(.047)***	-.352(.007)***
Constant	1.11(.066)***	-.416(.009)***
Wald chi2	88471.58	243747.62
P>chi2	0.0000	0.0000
Endogenous		
Plant Management	.107(.060)*	.034(.031)
Plant Management and Water Management	.347(.055)***	.019(.33)
Plant Management and Soil Management	.155(.042)***	-.021(.038)
Plant Management, Water Management and Soil Management	.320(.032)***	.061(.026)**
Gender of HoH (male=1)	-.037(.036)	.115(.033)***
No. of family members	.008(.009)	-.001(.007)
No. educated members (higher than 10th)	.015(.011)	.033(.010)***
Size of landholding	-.007(.005)	.040(.006)***
Active family labourers	.015(.011)	.003(.009)
Assets owned	-.0003(.007)	.006(.007)
Access to off-farm activity	.025(.027)	.002(.023)
Chikmagalur District (Karnataka)	.105(.040)**	.078(.50)
Shahdol District (Madhya Pradesh)	-.254(.047)***	-.227(.047)***
Sidhi District (Madhya Pradesh)	-.616(.050)***	-.336(.041)***
Keonjhar District (Orissa)	-.135(.043)***	-.308(.045)***
Mayurbhanj (Orissa)	-.314(.045)***	-.307(.045)***
Constant	1.12(.065)***	-.368(.055)***
Wald chi2		502.88
P>chi2		0.000
Selection terms (λ)		
Plant Management	-.159(.037)***	.128(.002)***
Plant Management and Water Management	-.011(.037)	-.068(.002)***
Plant Management and Soil Management	-.006(.051)	.065(.002)***
Plant Management, Water Management and Soil Management	-.108(.017)***	-.140(.002)***

Note: The baseline is farm households that did not adopt any SRI. Sample size is 386 and 200 simulation draws were used. ***P < 0.01, **P < 0.05, *P < 0.1. Robust standard errors are in parentheses.

5.5 Conclusion

The chapter made an attempt to analyse the determinants and impacts of the adoption of five mutually-exclusive combinations of SRI on yield and household income using a multinomial endogenous treatment effects model. Farm household survey data were collected from a sample of 386 households from selected districts of three States—Karnataka, Madhya Pradesh and Orissa. As in most adoption studies in general and in SRI adoption studies in particular, we find that the decision to adopt is a function of household assets, irrigation facility, information about SRI, contact with extension services, fear of poor yield, cultivation of other crops etc. Household assets, irrigation, information, extension services etc., increased the likelihood of household adopting SRI whereas fear of poor yield, cultivation of other crops etc., decreased the likelihood of adopting SRI.

Regarding the impact of adoption of SRI on welfare outcomes, the results showed the sample selection bias especially if the income equation is estimated without considering the adoption decision. In the results of the exogenous and endogenous adoption decisions there were differences in estimates for income; however, in the case of yield, all combinations of SRI had a positive and significant impact on yield in both the set of results. The positive impact of adoption of SRI on income was noted when households adopt all combinations of SRI as seen in the results from endogenous analysis. In general, the adoption of various combinations of SRI had a positive impact on yield as compared to non-adopters. Similarly, the adoption of full package of SRI had a positive impact on income as compared to non-adopters.

The impact estimates also highlight the fact that there were considerable differences in the adoption across different States. Even with relatively high level of adoption of SRI in states like Orissa and Madhya Pradesh as compared to Karnataka, the welfare outcomes of adoption was relatively low. This highlights the inherent differences in development. Although, education level of the farm households plays a key role realising the full benefits of SRI, an enhancement of irrigation management practices is also important.

Chapter 6
Conclusion and Policy Implications

Rice plays a major role in meeting the food requirements of half of the world's population. Around 90% of the rice produced is consumed in the Asian region and for people who live in Asia rice security is equivalent to food security. As a major producer and consumer, India plays an important role in the global rice economy. Nonetheless, rice cultivation in India today suffers from several interrelated problems. Increased productivity achieved during the green revolution period through input-intensive methods of high water and fertiliser use in well-endowed regions are showing signs of stagnation and concomitant environmental problems due to salinisation and waterlogging of fields. Since virtually all suitable land is already under cultivation, raising productivity—through simultaneous reduction of negative environmental consequences and improvement of the efficient use of resources—seems to be the only way forward.

SRI, which originated in Madagascar, is widely recognized as a promising systemic approach to rice production by reducing negative environmental effects. SRI was widely believed to enhance yield and substantially reduce water and other input requirements (Stoop et al., 2002; Uphoff, 2002: Uphoff, 2003) through changes in the management of plants, soil, water and nutrients (Satyanarayana et al., 2007).

SRI is not a technology but a different method of cultivation. Unlike other technological innovations, SRI does not require costly investment. So, SRI is a knowledge-based innovation. Therefore, one would naturally expect SRI to be widely disseminated and successfully adopted. Despite the potential benefits of SRI, its adoption rate is very low and also varies from region to region. Studies point out factors such as poor water control, lack of awareness, skill-intensive nature of the method, difficulty in getting labourers etc., as constraints in adoption. These could be the reasons for the common practice of partial adoption of components observed in most of the regions that adopted SRI. These constraints are even more severe in a developing country like India. Against this backdrop, the present study analysed the factors influencing the adoption of SRI as well as the impact of SRI adoption on household income and yield. The study made the analysis from three different perspectives. First was the analysis of the factors influencing the intensity and depth of adoption by explicitly considering constraints which are relevant to SRI. Second was the analysis of the factors influencing the adoption of various components of SRI and the combinations of various components of SRI. Third was the analysis of the adoption and impact of SRI on income and yield in a joint framework.

While the first two chapters were devoted to introduction, study area, data collection and socio-economic profile of the households, the third chapter made an analysis of the determinants of the intensity as well as the depth of adoption of SRI in India. The intensity is defined in terms of the number of acres devoted for the cultivation of SRI, whereas the depth is defined as the number of SRI components adopted. In a developing country, it is quite possible that markets function in an imperfect manner. Therefore, any technology adoption can be plagued by multiple constraints. Most of the earlier studies on technology adoption in agriculture assume that markets function perfectly and, therefore, agents do not face any information asymmetry. However, some recent studies have incorporated the multiple constraints in technology adoption in agriculture (Shiferaw et al., 2008; Shiferaw et al., 2015). Nonetheless, there are hardly any such studies on SRI in general and for SRI in India in particular. Farmers who function in an imperfect market setting may lack information and access to seed, credit etc., which are crucial for adoption. Therefore, even a farmer with positive demand for adoption may not be able to adopt a new technology owing to several constraints. These could result in inconsistent parameter estimates (Shiferaw et al., 2008; Shiferaw et al., 2015). In line with Shiferaw et al. (2008; 2015), the present study developed a multi hurdle model which is a modified double hurdle model.

The descriptive analysis showed that out of 386 households interviewed, only 38 farmers did not have any information regarding SRI. This constitutes only 10 per cent. The results, therefore, provide us with some policy relevant insights. The lack of adoption was not greatly due to lack of information about SRI but could be due to other constraints. Around 63 per cent of non-adopters did not have access to extension services, thus pointing to the importance of extension services in the dissemination and adoption of SRI. Unlike other agricultural technologies, SRI is not a technology or an improved variety of a seed; instead, it is a set of innovative ideas. Similarly, around 60 per cent of non-adopters faced difficulty in getting labourers and in irrigation. Difficulty in getting labourers was a problem even among adopters of SRI. As far as the irrigation is concerned, although SRI is supposed to be less irrigation intensive, the analysis showed that the type of land is very important for effective irrigation. Land selected for SRI should be well levelled and should not have the problem of waterlogging. Also, while irrigating the plot, water should spread evenly across the field. Additionally, farmers must have their own irrigation facility so that irrigation can be done whenever needed.

As observed during the field visits, and as also highlighted in the existing literature, the present study decided to explicitly consider the above-mentioned constraints in our model. The constraints that are also generally highlighted in the adoption literature are access to seed, access to credit etc. Nonetheless, in the context of our present study, we do not consider these as major constraints in the adoption of SRI. This is due to the fact that neither SRI is specific to any seed variety nor does it require costly investment.

The results from the multi hurdle analysis showed that younger and large farmers had greater access to information. Gender of the head of the household, education, membership in farmers' organisations etc., were was crucial in getting access to extension services. Age of the head of the household, cultivation of only rice, farming as main occupation, access to off-farm activity etc., were found to be important in increasing the likelihood of access to labourers. The farmers with farming as main occupation and rice as main farming face relatively less difficulty in getting access to labourers indicating that social network and long-standing relationship with labourers play an important role. As far as the disparities among districts in terms of constraints were concerned, the disparities were the highest in the case of access to information and this was followed by extension services. This study, therefore, indicates the lacunae of information and extension services in wider dissemination and adoption of SRI practices.

The results from the final adoption decisions showed that the factors influencing the intensity of SRI adoption was slightly different from the factors influencing the depth of SRI adoption. Nonetheless, the common factors that influence both intensity and depth were assets owned and rented, number of improved rice varieties known, membership in input supply cooperatives, and the fear of poor yield. So, it is clear that financial capital such as initial wealth and social capital such as membership in farmers' organisations are very crucial in terms of their effect on the adoption of SRI. Wage rates for labourers were crucial in the depth of adoption of SRI. Wage rates of woman labourers were negatively related to adoption whereas wage rate for male labourers were positively related to adoption. This is perhaps due to the fact that the shift away from manual weeding to mechanical weeding creates more demand for male labourers. So, the skill-intensive nature of mechanical weeding leads to higher demand for male labourers and, thus, to higher wage. This indicates a gender-biased nature of technical change.

The fourth chapter analysed the probability and level of adoption of multiple packages of SRI. SRI is a package of components and partial adoption is commonplace. Therefore, it is important to understand why farmers adopt only some and not all modified practices. We used MVP and ordered probit models to jointly analyse the adoption of multiple packages and the number of SRI packages adopted while taking into account the interrelationship among them. Our approach extends the existing empirical studies by allowing for correlations across different packages of SRI. The results show that various economic, institutional and access-related factors shape farmers' adoption of SRI packages.

The adoption of agricultural technologies in developing countries is mostly dependent on farmers' economic ability to access new technologies. The present study found a significant and positive relationship between households' assets and adoption of SRI packages. In line with the results from multi hurdle model, the results from MVP and ordered probit model also showed that certain fixed social bias and gender disparities were affecting the adoption. Despite considerable disparities in wage rates between male and female labourers, the analysis showed that female wage rates reduced the likelihood of adoption of almost all packages. Interestingly, the male wage rate generally increased the likelihood of adoption. The results highlight the skill-intensive nature of SRI adoption and the gender implications of SRI adoption.

Information and extension services are also very important driving-forces in enhancing adoption of SRI. Our results showed the importance of extension services in influencing adoption decisions. The insignificant impact of NFSM districts dummy on SRI adoption is an eloquent testimony to the fact that the objective of increasing rice production by promoting SRI under the Government's food security mission was not yielding the desired results. Additionally, most farmers who had been in farming for several years were not attracted to new methods. Also, farmers who were remotely located from the main market had higher likelihood of adopting SRI. This indicates the possibility of cultivating commercial crops by those farmers who were located close to the market. Most farmers interviewed did not consider rice farming as a commercially-viable venture and instead reported that the production was mainly for self-consumption and sale in the local markets.

The study also revealed the importance of investment in such infrastructure as irrigation in promoting SRI. Although, SRI requires less water as compared to traditional method, farmers require their own irrigation facility for the purpose of proper water management which is an essential component of SRI.

The need for social capital and networks were also observed in our analysis. The membership in farmers' organisations such as input supply cooperatives increased the likelihood of SRI adoption. This implies that policy makers need to focus on establishing and strengthening local collective institutions. Local institutions can play a crucial role in providing farmers with timely information, inputs and technical assistance.

The fifth chapter analysed the determinants and impacts of the adoption of five mutually-exclusive combinations of SRI on yield and household income using a multinomial endogenous treatment effects model. As in most adoption studies in general and in SRI adoption studies in particular, we find that the decision to adopt is a function of household assets, irrigation facility, information about SRI, contact with extension services, fear of poor yield, cultivation of other crops etc. Household assets, irrigation, information, extension services etc., increased the likelihood of household adopting SRI, whereas fear of poor yield, cultivation of other crops etc., decreased the likelihood of adopting SRI.

As regards the impact of adoption of SRI on welfare outcomes, the results showed that various SRI combinations had a positive impact on income, when the impact on income was considered outside the joint estimation framework. When we consider the joint framework (adoption and impact together), the analysis showed that only the total combinations of SRI had a positive impact on income. However, the impact of SRI on yield was obvious in both the cases. Both the endogenous and exogenous adoption decisions had an impact on yield.

The impact analysis also showed that there were considerable differences in the impact of adoption across different States. Even with a greater adoption of SRI in states like Orissa and Madhya Pradesh as compared to Karnataka, the welfare outcomes of adoption was relatively low. This highlights the inherent differences in development. Although, education level of the farm households plays a key role realising the full benefits of SRI, an enhancement of irrigation management practices also assumes significance.

Briefly put, the three set of analysis undertaken in the study did not show any conflicts; instead, they provided more or less similar insights into the factors affecting the adoption. Although, lack of information did not turn out to be a major cause for non-adoption, there were considerable disparities in level of information across different districts studied. Extension services were found to be crucial and the results were consistent in all the models. Both the social and the economic capital of the farmers were found to be very important. Infrastructure-related issues such as irrigation also play a dominant role. Farmers who had been in farming for several years were found to be very sceptical of adopting SRI, and risk aversion also played a role. But the most important revelations were in terms of fixed social bias and gender disparity. Despite considerable disparities in wage rates across male and female labourers, the study in general observed that female wage rate reduced the likelihood of adoption whereas male wage rate, in most cases, increased the likelihood of adoption. As mentioned earlier, this is due to the fact that the shift away from manual weeding to mechanical weeding resulted in greater demand for male labourers. The government's interventions in promoting SRI through the national food security mission did not seem to have had any impact.

The impact of SRI in enhancing rice yield and household income were observed in the analysis. The wider adoption of SRI can contribute to promoting not only sustainable agricultural practices but also for greater food security provided the constraints that the farmers are facing are addressed with appropriate policy interventions.

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Annexure I & II

Enhancing Rice Productivity and Food Security: A Study of the Adoption of the System of Rice Intensification (SRI) in Selected States of India.

Response to the Reviewer's comments

	Reviewer's Comments	Author's response
1.	Objectives are not clearly spelt out	I have re-written the objectives.
2.	Methodology is innovative, useful and appropriate	Response not required
3.	The report addresses a very important topic- a new and innovative practice that could be a powerful policy tool for food security in coming days. Given the contradictions that surround SRI as against other technologies, evaluation is important. The study also uses advanced econometric methodologies that can in principle take account of much of the complexities that arise in any study of technology or practice which itself is a complex in its constitution. Studying its adoption and impact raises several methodological issues that need to be overcome.	Response not required
4	The write up in all aspects including the discussions of methods is tortuous. Given the policy focus of the whole purpose of the research, the writing needs to be greatly simplified, organized and made reader friendly spelling out the outcome and usefulness clearly.	I have made an attempt to make it simple, organised and more reader friendly.
5	The objectives of the study are not clearly mentioned. One finds a statement that can meet this purpose in the second sentence of section 2.2 in chapter 2 on Study area. The objective can be elaborated a little more possibly with numbered points and in any case it should be in a separate section with the indicative heading or at least pushed to section 2.1. Probably the objective	As mentioned already, the objectives have been re-written.

	should be discussed clearly in Chapter 1 under a clear heading although the chapter too does discuss the objectives in a dense and convoluted way. Thus Chapters 1 and 2 both need to be reorganized and edited with reduced overlaps and repetitions.	
6.	Chapter 2 is disorganized. Socio-economic profiles can be a part of a section on Data which itself is missing or they can preferably be organized as a section within the results as the tables are outcome of empirical analysis.	I have re-written chapter 2.
7.	The data collection is preceded by analytical classification of the study area based on states, districts, NFSM and SRI. Discussion of the same is tedious. A diagram can more clearly represent the different classifications like NFSM and non-NFSM, SRI and non-SRI etc. replacing much of the text. Moreover, a table must be given for the sample constitution with a break-up for all the categories, giving sample sizes of each category. In fact, the sample sizes- total (most important), SRI and of the control group are not found easily in the text by a reader. Much of the discussions can be replaced by a clear table and/or a diagram keeping only the justification of selection in the discussion.	A table is added to show the break-ups for all the categories, giving sample sizes of each category. I have not replaced the text with diagram as I felt it is better to retain the text.
8	The socio-economic profiles are given for the whole sample categorized properly by Adopters and Non-Adopters. However further break up by NFSM and non-NFSM may be given to assess the association of NFSM with SRI. Table 2.3 gives the sources of information but the word ‘sources’ is not found and may be inserted appropriately without the sources of information getting mixed up with mere access to information. Thus the tables need to be organized, edited and suitably titled and labeled to prove informative and meaningful. Some of the results by states may be given in the appendix to maintain focus. There may be a section on Methodology	I have made the corrections as per the suggestion. But since I have simplified the discussion of methodology I have retained the same in the main text rather than moving it to appendix.

	where the different methods in all the following chapters can be introduced though not described in detail. The study uses several methods but other methods used are not explained in the same detail as the multiple-huddle method.	
9	The Conceptual Framework in Chapter 3 seems to outline the method followed in this particular study- so the renaming the section can be considered. The mathematical notations used serious re-look. There are cautions about correctness, clarity and duplication. The use of A for adoption as well as for other behavioural variables and P for multiple subjects like probability, pairwise correlation and a particular SRI practice are examples. Subscripts/superscripts in equations 2 and 8 make the presentation confusing. Probability with a letter from alphabet in parenthesis is not meaningful when that letter is not defined as any Event while in many cases the correct expression is also used.	Chapter 3 gives the conceptual framework followed by the discussion of methodology. I think the conceptual framework is important so the heading “conceptual framework” has not been renamed. There are separate headings for both conceptual framework as well as econometric model.
10	The multi-hurdle model is appropriate and explained in Chapter 3 although the discussion can be much more concise. The notations and equations as already mentioned may again be checked with care.	I have made the discussion much more concise.
11	Table 3.1 is a very useful table and must be refined further for helping readers to understand all the result tables. All the variables in Table 3.1 should specified without ambiguity. For example for HoH Gender describes Male-1 but the value taken by female is not provided. The same gender variable is titled variously as gender, a male head etc. in the different tables. This is just an example. The recommendation is to make table 3.1 complete without leaving any specification to the imagination of readers with their time scarcity and to use uniform variable names as specified in table 3.1 in all subsequent tables. Variable names in other tables, also	I have maintained the consistency in naming the variables by renaming the variables.

	specified in table 3.1 must be made more self-clarificatory. Thus the variable 'Information' may be renamed 'Access to Information'. Similarly, Education, Labourer, Off-farm activity and such other variable names may be suitably altered to convey the meaning or they can be very carefully defined in Table 3.1.	
12	Chapter 3 estimates adoption of SRI as measured by intensity and depth along with the factors associated with final adoption and chapter 4 estimates adoption as probability of adoption broken into different practices that make up adoption of SRI. The methodology of Probit model and ordered Probit model must also be given in the text as done in the earlier chapter (including multi huddle). My recommendation is to arrange all detailed methods of different chapters in corresponding sections provided in the appendix. The reader may be guided to the appropriate appendix for the method when discussing the concerned issue in the chapters which can only mention or give short outlines of the methods if necessary.	I think I have given enough discussion of multi variate probit model and ordered probit model. Additionally these are the widely used methodologies unlike the multi-hurdle models. So I thought it is important to discuss the multi hurdle model in a slightly more detailed manner. As mentioned already the discussion of the methods has been retained in the main text as the discussion of methods are more simplified now.
13	Chapter 5 again takes up adoption and repeats much of the theory behind the model variables. This seems to be repetitive and confusing.	The chapter 5 analyses the adoption and the impact (outcome variables-yield and income) in a joint framework. This is important as the outcome variables can be correlated with the factors influencing adoption and therefore there can be an issue of endogenity. To address the endogenity problem, the analysis of the impact of SRI on rice yield and income is undertaken in a joint framework of adoption and impact using the mutli nomial endogenous treatment effects regression technique.

14	In section 4.2 in chapter 4 six SRI practices are listed but in the models reported in the same chapter (page 40) seven practices are considered. Such mismatches may be avoided by presenting the list in consistency with the models. Chapter 5 again uses in the first stage, outcome variables that reflect adoption of SRI but denoted as soil management, plant management and water management all associated with SRI. Why the use of another set of categorization was necessary may be explained though the reviewer would have preferred maintenance of consistency and continuity for avoiding confusion in a single study.	SRI consists of 6 major practices. The literature mainly talks about 6 practices. However in my field visit, I observed that most farmers, despite allowing wider spacing, were planting more than one seedling. Therefore the practice-Single seedling at wider spacing-is divided into two in my analysis. This has been clearly discussed in chapter 4. Chapter 5 attempts to analyse the impact of SRI on yield and income using the mutually exclusive combinations of SRI packages. Since there are 6 packages of SRI, the mutually exclusive combinations given by the STATA was much more than what the model can estimate. As a result I had to focus on the three main principles of SRI-plant management, soil management and water management. These three principles gave me the choice of 5 combinations comprising three major principles.
15	A few results of policy relevance do come out such as the role of access to irrigation, extension, input supply, female wage (explained appropriately but raising questioned). That the choice of non-adoption is not due to lack of awareness but inadequacy of extension and labour availability and that SRI does reach poorer farmers are significant finding but on the whole the variables chosen are based more on conventional practices in literature than policy use and scientific rationale. The age and sex of the head of household need not be important unless checked against family composition, as heads may not always have the decision	These comments will be taken into consideration while publishing the research.

	power. Not surprisingly many of these household attributes emerge as insignificant effects in statistical terms and even contradictory among the different equations for specifying the adoption. Some of the variables are not purely exogenous such as the fear of poor yield, which may be related to experience or misplaced knowledge of SRI and may not even apply to non-SRI. Such an analysis of drivers of adoption though important can be done separately by cross-tabulating perceptions and other possible factors with adoption if possible. Some of the variables are overlapping and not independent such as Number of family members and Active family labourers, age and number of years in agriculture (presumably of head only). These comments may be taken into account in future when publishing out of this work.	
16	Although the author has commendably attempted to provide rationale for individual econometric results using theory or evidences from other studies some of the explanations raise questions too. The relation between Age of household head and depth of adoption is stated to be negative and significant in page 32 whereas the coefficient is not seen to be significant in page 34, neither on intensity of adoption in page 30. The signs of coefficients of male and female labour and adoption are explained interestingly backed by theory in page 31 but there is a total confusion about which is the explanatory variable and which is the dependent variable (wage and adoption) creating some simultaneity issues that are avoidable. Such explanations need to be checked with rationality and corrected.	I have made the corrections.
17	Besides academic exercises in econometrics some illumination of the SRI practices and a comparison with other multiple practices that make up non-adopters would be useful in Chapter 1. Some linkage with food security may be brought out at least through discussion of the results. There is a dominant focus on adoption of SRI and the impact on income or food security is	I have tried to the highlight the link between SRI adoption, productivity, household income and food security in the conclusion.

	underemphasized both in methodology and analysis.	
18	**Overall view on acceptability of report** Author is requested to incorporate the comments to the extent possible before submitting the final report. The report needs re-writing to make it concise, reader friendly and policy focused. Mathematical notations may have to be revised and specifications stated with greater clarity for a good report. More substantial revisions of the econometrics can be considered later if the report is published.	I have tried to incorporate the comments and suggestions as far as possible.