Systematic Rice Intensification in Bihar among Santhal Tribals
An Econometric Study of Panel Data

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Abstract

It is often difficult to determine the extent to which observed output gains are due to a new technology itself, rather than to the experience of the farmer or the quality of the seed on which the new technology is tried. We introduce a method for properly attributing observed productivity due to new production methods by controlling for land under cultivation, farm labour, technology adopted, and credit absorbed. In our study of new system of rice intensification (SRI) among 101 Santhal tribal households in Chakai block, Jamui district of Bihar about $2/5^{th}$ of the observed agricultural income gains appear due to higher labour productivity, use of irrigation and improved soil crop management. The farmers seem to keen adopter of technology, and have absorbed well improved farm practices advocated by Action for Social Action, a Bhopal based agriculture extension agency working in Jamui. The study shows that to sustain farm yield among small holders, there is an urgent need for reliable extension service, greater access to credit from mainstream banks, and introduction of water efficient crops and irrigation practices.

1.0 Introduction and Problem Statement

Technological change is the primary driver of long-term agricultural growth. However, technology alone is insufficient because its adoption by farmers may be slow, partial, reversible, or absent all together. Cross-sectional variation in the extent and rate of technology diffusion is often dependent on the characteristics of the farmer, farm size, educational attainments of the farmer, access to extension, credit services, attitude towards risk, and irrigation facility. Though a technological breakthrough like SRI may offer high returns, choices by poor farmers lacking information, finance, and farm inputs may be sub optimal.

Establishing true gains attributable to a particular technology under prevailing farm conditions and farmer management remains a methodological challenge. The observable and unobservable characteristics of farmers and their farms influence technology adoption decisions, input application choices and observed output. Standard cross section analysis of yields, yield risk and labour productivity under alternative treatment design overlook the individual characteristics of farmer in adopting the new technology. The farmer, being risk averse, does not completely move mover to new technology, it continues in part with old, traditional low risk low gain methods.

We explore whether through observations of four-year production data of SRI and traditional method, if any trend in increase adoption or dis-adoption can be discerned. This paper offers a method to resolve the methodological challenge by decomposing the sources of output gains – both in mean and variance – that are rightly attributable to the new technology, farmer, and extension services.

2.0 Structure of the Paper

In the next section of this paper, we explain the special features of SRI and its' relevance to rainfed farming in India. Section 4.0 reviews literature related to SRI in other countries. Section 5.0 introduces the methodology used in the study starting with a general description of the study area, farms and farmer characteristics. Section 6.0 describes the method of data collection and comment on the quality of the data used. Section 7.0 justifies the selection of econometric model, and its' limitations. Section 8.0 presents the results of econometric analysis. Section 9.0 concludes with few remarks on policy recommendation.

3.0 SRI Explained

The *System of Rice Intensification,* known as SRI is a climate-smart, agro ecological methodology for increasing the productivity of rice and other crops by changing the management of plants, soil, water and nutrients. SRI is methodology aimed at increasing the yield of rice produced in farming. It is a low water, labour intensive, organic method that uses younger seedlings singly spaced and typically hand weeded with special tools. The French Jesuit Father Henri de Laulanié in Madagascar developed it in 1983.With the help of universities like Cornell, the system has been tested and spread throughout the rice growing regions of the world. SRI methodology is based on a set of principles based on the synergy among several techniques. Briefly, the package of SRI management practices advocated by ASA Jamui is:

Rice Plantation

- Seeding on moist bed covered from excessive sun shine and frost
- Rice seedlings are transplanted younger usually between 8-12 days old with one plant per hill
- Widely spaced in square grid of 25x25 cm or wider in good quality soil

Soil Management

The soil is enriched with organic matter to improve soil structure, nutrient and water holding capacity and favour microbial development.

Water

Alternative wetting and drying of rice field is done before draining the paddy 2-3 weeks before harvest. A 1-2 cm layer of water is introduced applied during the vegetative growth period, followed by letting the plot dry until cracks become visible, at which time a thin layer of fresh water is released.

Nutrients

The majority of farmers of farmers complement the organic matter amendment with chemical fertilizers, most often urea, in order to achieve a balanced fertilization of the crop.

Weeds

Controlling the water level to allow for aeration of the roots during growth period of the plant leads to vigorous growth of weeds. Frequent use of hand held mechanical push/cono weeders ideally after 15-20 days after transplanting, repeated every 10-15 days up to initiation of fruiting stage adds significant amounts of household labour.

Six key elements distinguish SRI farming practices from traditional rice growing methods. They are

- Seed treatment & seed shorting to minimise fungal disease and promote healthier seeds rather than unhealthy & untreated seeds,
- transplanting seedlings much earlier than in traditional calendar and planting only one seedling per hill, rather than many,

- spacing plants wider apart than in traditional methods and arranging them in a square pattern,
- applying water intermittently instead of continuous flood irrigation,
- using rotary weeding to control weeds and promote soil aeration, and
- improved soil conditions through applying organic or balance manure.

Based on these *principles*, farmers can adapt recommended SRI *practices* to respond to their agro-ecological and socioeconomic conditions. Adaptations are often undertaken to accommodate changing weather patterns, soil conditions, labour availability, water control, access to organic inputs, and the decision whether to practice fully organic agriculture or not. These practices work because wider spacing and single planting increase plants' exposure to sunlight, air and nutrients, which in turn produce stronger stalks, more tillers, sturdier plants and larger and deeper root systems. Sporadic irrigation, which causes soil cracks, also promotes soil aeration, nutrient growth and root elongation, because soil that isn't kept flooded forces roots to grow larger and deeper to remain healthy, making them more resistant to periods of water stress. The proponents claim that SRI also reduces production costs, especially for seeds, fertilizers and energy bill for pump irrigation.

The difference between SRI and conventional rice cultivation can be summarised below:

Table 1:Comparison of SRI and Conventional Rice Cultivation Practice and Management

	Nalanda		Jamui	
Practices	SRI	Conventional	SRI	Conventional
Nursery management	Moist but well- drained soil	Flooded soil	Same as Nalanda	Same as Nalanda
Nursery seed rate	5 kg/ha	35- 40 kg/ha	Same as Nalanda	Same as Nalanda
Plant management				
Age of seedlings	12 days	24 days	7-12 days	25-31 days
Transplanting	Single seedlings in 25 x25 cm grid	Random transplanting	Same as Nalanda	Same as Nalanda
Planting density	16/m2	~60- 70/m2	Same as Nalanda	Same as Nalanda
Soil- water management	Sprinkler irrigation 1-2 cm layer	Flooding 10 cm or higher	Same as Nalanda	Same as Nalanda
Weed management	Soil- aerating weeding –every 10 days	Sporadic application of herbicides	Soil- aerating weeding – after 15-20 days after transplanting, repeated every 10-15 days up to initiation of fruiting stage	Manual weeding or no weeding

Nutrient management	More organic soil amendments: farmyard manure and vermi-compost with green manure	Recommended NPK applications, with green manure	Same as Nalanda	Chemical NPK application with or without green manure
Nalanda data Adapted from Diwakar, M.C., Kumar, Arvind, Verma, Anil, and Uphoff, Norman (2011). Report On The World- Record Sri Yields In Kharif Season 2011 In Nalanda District, Bihar State, India: http://www.indiawaterportal.org/ Jamui data: Samim Molla, Area Manager, ASA Jamui, Personal communication 22 Oct 2014				

SRI is becoming part of mainstream agricultural policy. Asia is fast adopting SRI. Prof. Norman Uphoff, a professor in Department of Government and former director of the Cornell International Institute for Food, Agriculture and Development at Cornell University, Ithaca, estimates that by 2013 the number of smallholder farmers using SRI had grown to between 4 and 5 million (quoted in Vidal 2013). These innovative farming methods have produced impressive results around the world. Sichuan, China has increased their rice yields by 40%. Andhra Pradesh, India has reduced its seed requirements by 90% and used 50% less water while increasing yields of up to two tons per hectare on average. In Mindanao, the Philippines, the average yield per hectare reached 10 tons, twice the amount yielded under conventional practices, while reporting an 80–90% reduction in seed use. Since 2002, the Government of Indonesia has been supporting the dissemination of SRI throughout the country by funding research and training farmers to utilise the methods (McClelland, S. 2002, page 191). In limited trials in Indonesia, reports indicate reduction of fertilizer input by 50% and lowering production costs by 20%, but realisation of 30–80% higher market prices compared with traditionally grown rice because of its better flavour and quality. In India, SRI has started becoming popular with farmers. Farmers in states such as Tamil Nadu, Andhra Pradesh, Odisha, Bihar, and Tripura have been practising SRI and gaining good results from it for many years now. According to a report by Dass and Dhar (2014), the area under SRI management in Tamil Nadu has now reached about half of the State's rice area. It says that in Tripura, almost 3,50,000 farmers are practising SRI in about 1,00,000 hectares, almost half of the State's rice area. In a study (Krishnagopal 2010, pg 6, 16) found that in Purnea, Nalanda and Gaya yield per hectare in pre-SRI cultivation were 35, 30, and 30 quintals, compared to 60, 70 and 55 quintals in the same districts. The yield under SRI was approximately 70%, 133%, and 130% higher than that under traditional practice. The average cost incurred on one hectare is around Rs10, 000-11,000 on both traditional as well as SRI method. (Rs 7200 + irrigation + labour cost + land preparation).In 2011 a young farmer named Sumant Kumar of Nalanda, Bihar set a new world record in rice production of 22.4 tons per hectare using SRI, beating the existing world record held by the Chinese scientist Yuan Longping by 3 tons.

The SRI approach differs from traditional rice cultivation practices followed by Santhal farmers in Chakai, the study area of this paper. Santhals traditional way of paddy cultivation in uplands involved broadcasting the seed in puddled fields without any adherence to row spacing, or periodic weeding. The yield was natural low in the range of 30 – 35 quintals.

While large number of Santhals has adopted SRI, one is puzzled why the adoption of the oft-asserted superior method is not universal. First, the adoption rate has been low – hovering around 20% of villages where ASA is active and had introduced SRI. Second, most farmers who practice SRI continue to practice traditional methods on part of their land –particularly where irrigation facility is available or where due to topographic reasons, soil has higher levels of moisture. Third, some farmers after few years after introduction opt out of SRI. Given SRI's push by the agricultural extension agents of government of Bihar and NABARD, and it's oft-demonstrated superior productivity benefits, its' slow and limited uptake by farmers has puzzled ASA and raises questions about whether this new rice production method really offers all the total factor productivity gains its advocates claim.

4.0 Literature review

Rice is the staple food for more than half of the world's population and plays a pivotal role in food security, particularly in Asia (IRRI, 1997). Though statistics show that the share of rice in Asian economies as well as household food consumption is declining very rapidly (Trimmer 2010), in Bangladesh, Vietnam and much of Central and Eastern India over half of the daily caloric intake comes from rice. The pursuit of food security hinged on stabilising prices of rice in the major urban markets, and increasing production of rice every year in despite increasing cost of cultivation, and shrinking natural resources, like water.

There is small but growing literature on systematic rice intensification (Stoop, Uphoff and Kassam 2002). The literature falls mainly into two broad categories: a) those that focus on the socio-economic barriers in adoption of SRI as a technology by small holders (see Barrett 2004); and b) those that examine the scientific and empirical validity of the claims made by SRI in improving water efficiency and yield (see Kumar 2009).

Rural sociologists have long held that agricultural technology diffusion follows a classical normal distribution or bell curve (Rogers 1962) . The model indicates that the first group of people to use a new technology is called "innovators", followed by "early adopters", and late majority to eventually adopt a product are called "laggards". The demographic and psychological profiles of each adoption group specified by Beal, Rogers and Bohlen (1957) in US context found that more prosperous and educated farmers were among the early innovators, and the late majority and laggards were those who were conservative, had small farms and capital, older and less educated. Within SRI context, there is no evidence to support the classical "S curve" technology diffusion process. The SRI programs are directed towards women and small holders, and find the early innovators among them. Those women who are part of self-help group or such collective have higher tendency to experiment with new farming methods.

Approaches of the theories of technology diffusion can be divided into three groups: three groups: First is the most common approach is built around information and uncertainty (Mansfield, 1968). He argues that the potential adopters have little information about the new technology in the initial stage and when diffusion proceeds, others gain information from adopters and the speed of diffusion increases. Peer learning is a very strong, and effective way of spreading use of new technology. The second approach is based on the heterogeneity of adopters (Stoneman, 1987) and they concentrate on ―rank approach, where the price of a new technology falls because of falling unit cost of technology adoption. This is perhaps not so relevant in the case of SRI where the trigger of adoption is knowledge and attitude, not technology, equipment per se. The third is a strategic approach (Beath et al., 1995) where there are positive externalities for the adoption of new technology but excessive inertia can occur, and potential adopter may get stuck in a Pareto-inferior equilibrium. This again is less true for Santhal farmers under study. Though they are risk-averse, they are keen to experiment with new ways so long the returns are reasonable and risk-reward is within some rational bound.

SRI can be viewed as innovation. Susanne Padel (2013) describes a three stage process for diffusion to be realised. The whole process has three stages of:

1) invention, when ideas and concepts are developed or prototypes built;

2) innovation, focusing on how to put ideas into practice and

3) diffusion, with more widespread application of the innovation at different social and economic levels.

A major bottleneck in the context of agriculture innovation is nearly always understood as being only technical fix, with most experts not sufficiently aware of social/societal innovations that could be particularly important for achieving societal and economic goals. Agriculture progress has been largely associated as increasing efficiency through using new technology. The farmer’s know-how is replaced by “know-what” i.e. what input to use and when prescribed by agro input companies. In contrast, the systems perspective describes innovation in a more process-oriented, interactive and evolutionary way, whereby networks of organizations, together with the institutions and policies that affect innovative behaviour and performance, bring new products and processes into economic and social use (Padel 2013). SRI is best viewed as an iterative process where innovation takes places through learning, research or experience, but it cannot be considered as an innovation until it is applied and internalised by farmers themselves.

According to Uphoff (2008), the main obstacles to SRI adoption remain psychological as farmers who have taken up SRI themselves continually attest. An initial barrier is labour-intensity, while the methods are being adopted (Moser and Barrett, 2003). But once farmers acquire skill with and confidence in the methods, more and more evaluations show SRI to be labour-neutral or even become labour-saving (Uphoff, 2007). The most objective constraint on SRI adoption is water control, being able to manage irrigation systems sufficiently to provide reduced but reliable amounts of water on an intermittent basis. Careful soil management and pest control create anaerobic soil conditions which usually reduce pest and disease problems, but they can encourage some pests such as leaf folder or root-feeding nematodes.

The claims of System of Rice Intensification (SRI) to be a new, more productive and more sustainable method for cultivating rice have proved controversial (Glover 2011). The question at hand seems to be: is SRI better at delivering increased yield and other benefits to rice farmers, such as healthier soils, when compared with established recommended best management practices for rice production? One dimension of the controversy has centred on the imprecision with which SRI's component practices have been defined. Since SRI recommends a suite of flexible principles to be adapted to particular agro-ecological and socio-economic setting, it poses problem of scientific evaluation under standard fixed conditions. However, this apparent difficulty is chiefly an artefact created by conceptualizing agricultural methods as standardized packages. A process of translation is always necessary to convert theoretical models or norms into farming practices. Smallholder farming practices, being intrinsically constrained and contingent, rarely conform precisely to abstract norms of scientific enquiry. As an alternative, the notion of performance offers a useful way to frame a methodological and analytical approach to understanding what is going on in SRI.

More studies under controlled conditions are shedding light on claims SRI method claims to greatly enhance water productivity and grain yield. For instance Kumar et al (2009) evaluated SRI method in India at 25 locations for four years. Their unambiguous conclusion was: " *Results clearly indicated 7-20 per cent higher grain yield over the traditional irrigated transplanted rice. The varieties having better tillering ability and hybrids were found promising and recorded higher grain yield over HYVs with moderate tillering and scented cultivars. Root volume, dry mass, and dehydrogenase activity in soil (measure of microbial activity) was found to be higher in SRI method as compared to conventional method. SRI method reduced the seed rate by 80%, water requirement by 29% and growth duration by 8 –12 days; thereby enhancing the water productivity and per day productivity of rice cultivars. The water saving alone should be a strong justification for adopting SRI method wherever water is not abundant*." Looking into the potential of SRI as an environment friendly, input saving and yield enhancing strategy, Government of India has included SRI as one of the components under the

National Food Security Mission (NFSM). Several anti-poverty programmes including National Rural Livelihood Mission are promoting SRI.

While proponents and critics of SRI debate the claimed benefits and many questions about it remain unresolved, the benefits of SRI cannot be discounted. Although many of the technical aspect of SRI are contested, it clearly exists as a social phenomenon. The appeal of SRI lies in the claim that land and water productivity are increased while reducing the use of water, seeds and chemical fertilizers is monumental.

5.0 Study Area

Action for Social Advancement Bhopal, a development organisation, initiated water and land development work in Chakai block of Jamui district of Bihar following severe droughts affecting the area in 2009.

Chakai is located 51 KM towards South from District headquarters Jamui and 203 KM from State capital Patna towards west. Chakai is one of the 10 blocks in Jamui district. The total population of the Chakai block in 2011 was 2,34,932 (2001 187,034). There are 522 villages grouped in 23 Panchayats, and 0 towns in this block. Between 2001 and 2011, Chakai has recorded rapid increase in literacy; overall literacy rate was 49.12% in 2011 up from 36.11% in 2001. Increase in female literacy was even more impressive: from a mere 19.02% in 2001 to 36.95% in 2011. Scheduled caste and Scheduled tribe constitute 17.63% and 17.68% of the total population. The total area of Chakai is 72,659.83 hectares, 43% of which is under cultivation. As far as the land use pattern is concerned Rice and Wheat are the prominent crops. Small quantity of Maize, Jack fruit (Hindi Katahal, botanic name *Artocarpus heterophyllus*) and Mahua (Botanic name *Madhuca long folia*) are also grown by small landholders.

ASA works mostly with Santhal tribal households living below poverty line. They have limited arable lands on which low yield rainfed crops are grown. Significant amount of barren or wastelands exist, in the absence of land development measures these are used for open grazing. Supplementary subsistence is provided by minor forest produce, hunting, and fishing. Growing state control over forest resources and deforestation by organized by mafia is a matter of great conflict between Santhals and forest department. Of late, Naxalites have been able to feed on the general discontentment about mis-governance fuelling sense of injustice and alienation among tribals. The government agricultural extension service is totally absent. The lack of health care, education, and gender discrimination hit women hard. Hence, livelihood generation and increase of income of these tribal farmers by various means is a basic imperative in the area.

Paddy is widely grown in *Kharif* season. The average yield under SRI is 8.2 and traditional is 3.66 tonne[2]. The yield under SRI method and traditional method is given below:

Table 2: Comparison of Yield under SRI and Traditional Method of Selected Varieties in Chakai			
Sl. No.	**Variety**	**Production Technique**	**Avg yield tons/ha**
1	PR116	SRI	8.9
2	PR113	SRI	8.1
3	NDR 359	SRI	8.3
4	Lalat (local)	SRI	7.6
5	Jhiran (local)	Traditional	3.5
6	Lal Sita (local)	Traditional	4.0
7	Sita (local)	Traditional	3.5

All ASA supported farmers are organised under self-help groups. ASA uses individual household wealth ranking, Participatory Rural Appraisal and Focused Group Discussion and other sources to identify and vet farmers eligible to receive technical assistance for promoting SRI. In every village, ASA has a community resource person (CRP) who is available 24 x7 days to attend to the grievances of the farmers, and meet SHGs every week to pass on tips on specific SRI related topics.

6.0 Data

The data come from a study of 101 randomly selected farmers from 9 villages practicing SRI using the same rice variety in 8 villages in Chakai block, Jamui District in Bihar. In these villages ASA has popularised SRI cultivation which have become widespread. The sample farmers were interviewed in Santhali dialect by field survey assistants using a structured survey questionnaire about cultivation details, irrigation practices, household characteristics, etc. over two months of September and October 2014. 5% of the households were contacted by phone to cross check the data recorded by the survey assistants.

Santhal farmers commonly cultivate many small plots. In our sample, the mean size of plots was 0.20 hectares (i.e. 20 decimals). Our survey gathered detailed production information the household, on their sources of credit and information about improved agricultural practices.

[2]The official statistics on rice production in Bihar, India: between 2002 and 2011, yields varied from 0.79 to 1.60 tons per hectare. The period 2011-12 showed a good average yield of 2.1 tons per hectare, which was twice that of 2010-11 but not "miraculously" high compared to the last 10 years. Good yields under rainfed conditions in Bihar are on the order of 3.5–4.5 tons per hectare. (Dr. Bas Bouman in http://irri.org/blogs/bas-bouman-s-blog-global-rice-science-partnership/spectacular-rice-yields accessed on October 18, 2014)

Farm and Farmer Characterises

All the farmers surveyed are scheduled ~~caste~~ **tribe** women, 99% of whom had a modicum of education. The mean age was 35 years. Till recently, they relied on non-timber forest produce and menial labour work for existence. It is only in the last five years they have taken to farming in a big way.(see Table 3).

Table 3: Farmer Characteristics (n=101)	
Association with ASA Bhopal (in years)	2.73
Mean age of farmer (in years)	35
Per cent female	100
Religion	94% Hindus, 7% Christians
Per cent Scheduled Tribe	100
Per cent of farmers with standard 8 education or below Per cent of farmers with high school education or better	99% 1%
Number of respondents having mobile	2
Number of respondents having bank account	5

Farm holding is extremely small (approximately 1/5th of a hectare). There are no title deeds available for land, which technically belongs to the Forest Department, but occupied and tilled for several generations by the tribal farmers. On good quality land – with higher moisture – paddy is grown by traditional method; on uplands with modulating slope, SRI is practiced. Paddy cultivation is entirely rainfed, and lasts for 100 days during *Kharif* season (mid June-mid September). Wheat is grown during *Rabi* season in winter months (November-March).

Changes in income and output

The change in income due to agriculture is wide spread. Paddy grown under SRI method generated surplus which brought in cash through sales. The average sales per farmer were Rs. 3854, Rs. 5305, Rs. 6575 and Rs. 7900. Roughly this constituted 19.9%, 22.4%, 23.8% and 24.4% of total household income for the said four years. It is interesting to note that per household debt has also gone up from Rs. 17,154 in 2011 to Rs. 26,252 in 2014.

The year on year output growth was 15% in 2012, 13% in 2013, and 10% in 2014. Expressed differently, the growth in SRI paddy output in 2014 over 2011 base year period is 44%.

Type of Technology Adopted

The four major water, land, and crop related technologies adopted are

- Planting and weeding techniques (transplantation, periodic weeding etc.)
- Water harvesting (channelling water from streams, earth dams, wells etc.)

- Integrated soil fertility management (combinations of chemical fertilizers + residues + manure/compost)
- Land levelling a field within certain degrees of slope to improve water use efficiency

Of the various technologies adopted, farmers place maximum weightage on irrigation (400/1000), followed by soil fertility management (200/1000) and planting and weeding practices (200/1000), land levelling (150/1000).

Lot of peer-to-peer learning happens among farmers on transplanting, and weeding practices. Yet only 70% of the farmers surveyed practice transplanting and weeding, perhaps due to the burden of extra work it imposes. The farmers have universally adopted small scale water harvesting, land sloping and integrated soil fertility management by combining chemical fertilisers, residues, manure and vermi-compost.

7.0 Model Selection and Specification

The present analysis is performed on data collected on 101 respondents for four years of household panel data sets which are spaced one year apart. The panel nature of the data calls for the use of models which are appropriate for it. Accordingly, econometric estimations are done applying the two prominent panel data models: fixed effects and random effects models. These models, by virtue of their capacity to account for inter-temporal as well as individual differences, provide a better control for the influence of missing or unobserved variables. There are two common assumptions made about the individual specific effect, the random effects assumption and the fixed effects assumption. The assumption made in a **random effects model** is that the individual specific effects are uncorrelated with the independent variables. The fixed effect assumption is that the individual specific effect is correlated with the independent variables. If the random effects assumption holds, the random effects model is more efficient than the fixed effects model. However, if this assumption does not hold (i.e., if the Durbin–Watson test fails), the random effects model is not consistent.

A fixed effects model may be constructed as:

$Y_{it} = \beta X_{it} + \alpha_i + u_{it}$

Where:

-Y^{it} is the dependent variable observed for household i at time t

-X^{it} is a vector of explanatory variables for household i at time t

-ß is a vector of coefficients.

-α_i denotes unobserved household specific effects which are assumed to be fixed over time and vary across household i.

-u_{it} is the error term

The random effects model is:

$Y_{it} = \beta_1 X_{it} + \alpha + u_{it} + \varepsilon_{it}$

Where

- α_i (i=1….n) is the unknown intercept for each entity (n entity-specific intercepts).
- Y_{it} is the dependent variable (DV) where i = entity and t = time.
- X_{it} represents one independent variable (IV),
- β_1 is the coefficient for that equation
- ui_t is the error term showing between entity error
- ε_{it} is within entity error

The assumption behind the relationship between the X_{it} and $\alpha_i$makes the fixed effects and random effects models different. The fixed effects approach assumes that α_i is treated as non- random and hence make the correlation between the observed explanatory variables (X_{it}) and α_i possible. On the other hand, the random effects approach is applicable under the assumption that α_i is random and not correlated with X_{it} and puts it into the error term (Wooldridge 2003).

Hausman test is used to differentiate between fixed effects model and random effects model in panel data. Estimations employing both fixed effects and random effect model were done and the result compared using the Hausman test under the null hypothesis that the unobserved household effects are uncorrelated with the explanatory variables included in the model (see Green, 2008, chapter 9). The analysis accepted the null hypothesis (Prob>chi2>0.000). This implies that the unobserved effect and the other regressors are uncorrelated hence a fixed effect model produces consistent results and we should use fixed effects estimator. Thus, we report here the fixed effects model estimation results.

Table 4: Hausman Test for FE or RE?

```
. hausman fe re

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      fe           re          Difference          S.E.
-------------+----------------------------------------------------------------
      x1land |     .16727    -.4810168        .6482868        .2283399
   lx2labour |  -.0049012    -.0517445        .0468432        .0216289
   lx4credit |   .1400757     .2262095       -.0861338        .0113128
  lx3technew |   .2943303     .2636953        .0306349        .0031282
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       92.77
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

For additional confirmation, we ran Breusch-Pagan test (named after Trevor Breusch and Adrian Pagan) to test for heteroscedasticity in a linear regression model. It tests whether the estimated variance of the residuals from a regression are dependent on the values of the independent variables. The result for Test: Var (u) = 0 shows chibar2 (01) = 299.1 and Prob > chibar2 = 0.0000 shows absence of heteroscedasticity. These results indicate that if we do not take the problem of heteroscedasticity into consideration in the estimation, the parameter estimates will be less efficient.

Our model specification is as follows:

$Y_{it} = \beta X_{it} + \alpha_i + u_{it}$

Where:

- Y_{it} is log of income from agriculture (i= 101 entities, t =2011-2014 for 4 years)
- X_{1it} Land under SRI cultivation for household i at time t
- X_{2it} Log of labour man days employed for household i at time t
- X_{3it} Log of Farm technology for planting, weeding, water harvesting, soil management, land levelling adopted for household i at time t
- X_{4it} Level of debt from all sources

-α_i denotes unobserved household specific effects which are assumed to be fixed over time and vary across household i.

-u_{it} is the error term

In the following, we describe the variables included in the model and our prior expectations about their relationship with agricultural productivity.

Agricultural income: SRI paddy contributes 80% of households' income from agriculture; hence it is a good proxy for entire farm income and household income.

Cultivated land: Land under cultivation is not fixed in the study area. The de jure owner of the land cultivated by Santhals is owned by the State; depending on their need and availability of labor, households either increase or reduce acreage. There is therefore, small variation in land under cultivation across the years.

Labor: Almost entire labor input comes from family labor. At times of need, neighbours and relatives are asked to chip. No external hired labor is used.

Technology: The weighed value of four major technologies has been factored in. Following weightage given by the respondents, the technology adopted has been given scores between 200- 400: availability of irrigation being 400, land levelling 150, and soil fertility management and planting and weeding practices scoring 200 points each.

Credit: Access to credit is anticipated to have a positive influence because it enables farmers buy more farm inputs. Since only 5 farmers have bank accounts, the major source of credit is local moneylenders.

8.0 Results

The estimation results of FE estimate are presented in below.

Table 5: Fixed Effect Model Results

```
. xtreg  lyincome x1land lx2labour lx4credit   lx3technew, fe

Fixed-effects (within) regression               Number of obs      =       404
Group variable: farmer                          Number of groups   =       101

R-sq:  within  = 0.8395                         Obs per group: min =         4
       between = 0.4406                                        avg =       4.0
       overall = 0.4651                                        max =         4

                                                F(4,299)           =    391.07
corr(u_i, Xb)  = 0.1494                         Prob > F           =    0.0000
```

lyincome	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x1land	.16727	.6340134	0.26	0.792	-1.080424	1.414964
lx2labour	-.0049012	.0327616	-0.15	0.881	-.0693737	.0595712
lx4credit	.1400757	.0276732	5.06	0.000	.0856167	.1945346
lx3technew	.2943303	.0143034	20.58	0.000	.2661821	.3224784
_cons	6.871429	.392014	17.53	0.000	6.099973	7.642885
sigma_u	.22939619					
sigma_e	.09196555					
rho	.86153203	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(100, 299) =    15.99          Prob > F = 0.0000
```

There are 404 observations involving 101 farmer households. The overall R^2 is 84%. As expected, the sign of land is positive, which means that with more units of land agricultural production goes up. What is surprising is that the sign for labor is negative, which confirms that incrementally less labor is required to produce a ton of paddy. The impact of surplus labor is reduction in overall income. Technology seems to play the most important part in determining change in household income. For 100 unit change in income, 29 units are accounted due to technology adoption and 14 by credit.

Since both land and labour is statistically insignificant, we run the equation without these two variables. Our new model specification is as follows:

$Y_{it} = \beta X_{it} + \alpha_i + u_{it}$

Where:

- Y_{it} is log of income from agriculture (i= 101 entities, t =2011-2014 for 4 years)

-X_{3it} Log of Farm technology for planting, weeding, water harvesting, soil management, land levelling adopted for household i at time t

-X_{4it} Level of debt from all sources

-α_i denotes unobserved household specific effects which are assumed to be fixed over time and vary across household i.

-u_{it} is the error term

The results are given below (Table 6).

Table 6: Results of Revised Fixed Effect Model

```
. xtreg  lyincome lx3technew lx4credit, fe

Fixed-effects (within) regression               Number of obs      =       404
Group variable: farmer                          Number of groups   =       101

R-sq:  within  = 0.8395                         Obs per group: min =         4
       between = 0.4398                                        avg =       4.0
       overall = 0.4648                                        max =         4

                                                F(2,301)           =    787.07
corr(u_i, Xb)  = 0.1491                         Prob > F           =    0.0000

------------------------------------------------------------------------------
    lyincome |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  lx3technew |   .2966943    .011795    25.15   0.000     .2734832    .3199055
   lx4credit |   .1407087   .0271776     5.18   0.000     .0872266    .1941909
       _cons |   6.852686    .225454    30.40   0.000     6.409021    7.296352
-------------+----------------------------------------------------------------
     sigma_u |  .22944764
     sigma_e |  .09167393
         rho |  .86234128   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(100, 301) =    18.20           Prob > F = 0.0000
```

We notice that R^2 remains high 84%, the P>|t| values remain statistically significant. Technology is the key driver to higher agricultural income.

Since a part of credit is used for acquisition of new technology, we examine possibility of collinearity between the two variables. We hypothesise that the joint coefficients of the variables is zero $H_0 = 0$. The results validate the null hypothesis.

Table 7 Parameter test of joint coefficients

```
. testparm lx3technew lx4credit

 ( 1)  lx3technew = 0
 ( 2)  lx4credit = 0

       F(  2,   301) =  787.07
            Prob > F =    0.0000
```

In accordance with our expectation, use adoption of new technology has its expected positive sign and is highly significant. Feleke and Gladwin (2003), Ramakrishna and Demeke (2002), Muluken et al. (2008), and Kidane et al. (2005) also found use of fertilizer positively and significantly related to higher crop productivity. This implies that households could improve their income by increasing use of modern technological inputs in their farm operations.

One of the repeated labour consuming works under SRI is equal spacing of seeding for which at least two persons are needed to hold a rope showing exact distance where seeds may be planted. With better water management, weed growth on SRI paddy field also increases. Many farmers go slow on weeding and seed spacing, particularly in third and fourth year.

Consistent with our expectation, credit is positively and significantly associated with income implying that the more livestock a household has the better its income security position.Increase in credit uptake is not due to SRI, though part of the amount is used to purchase seeds, fertilizers, and pesticides. ASA insists on external purchase of branded seeds, as productivity drastically falls if the same variety of seed is used over multiple years. Besides, with more production, more inputs of fertilisers and pesticides are needed. Credit is also used to meet emergency needs and new needs for consumer conveniences (such as mobile phone) and education of children.

9.0 Conclusion

The main objective of this study was to investigate how household income is associated with an important production variable, technology adoption, over time. Results from regression analysis are consistent with the descriptive analysis. In the regression analysis, technology adoption, particularly water management, and credit emerged as an important factor influencing household income.

Several important lessons can be drawn from these results. Firstly, both the descriptive and regression results highlight the critical role labour and technology adoption plays in enhancing income. This calls for policies that enhance farm extension services, such as education and training, and ease in accessing credit. ASA has been the primary source of extension services to SRI farmers in Jamui district. In line with Moser and Barrett (2003) study of SRI in rural Madagascar, we find that access to extension is extremely important for successful adoption of SRI.

Secondly, technology use is found to significantly impact farm incomes indicating that development interventions should coordinate efforts to encourage farmers use modern farm technologies; particularly those enhance access, use and conservation of water for irrigation.

Our analysis is restricted only considering the impact of SRI paddy. Some of the practices of SRI are easily transferable to non SRI paddy and also to wheat and vegetables grown in an intensified manner. As paddy productivity through SRI method reaches its peak, farmers are looking at other crops. A future research topic could be to examine if knowledge and practices of SRI paddy are applied to wheat and vegetables, and if so with what results.

References

Beath, J., Katsoulacos, Y., and Ulph, D. (1995). *Game-theoretic approaches to the modelling of technological change*, in: Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technological Change, Oxford, Blackwell, pp. 132-181

Bohlen, Joe M.; Beal, George M. (May 1957), *The Diffusion Process*, *Special Report No. 18* (Agriculture Extension Service, Iowa State College) **1**: 56-77. http://www.soc.iastate.edu/extension/pub/comm/SP18.pd

Dass A and Dhar S. 2014. Irrigation Management for improving Productivity, Nutrient uptake and Water-use Efficiency in the system of rice intensification: a Review. *Annual Agricultural Research*. New Series. Vol. 35 (2): 107-122.

Feleke, S. T., Kilmer, R. L., Gladwin, C. H. (2005) Determinants of food security in Southern Ethiopia at the household level. *Agricultural Economics*, 33 (3) 351 – 363.

Glover, D. (2012), The System of Rice Intensification: Time for an empirical turn, *NJAS-Wageningen Journal of Life Sciences*, Vol. 57, February, pages 217-224

Greene, W. H. (2000) *Econometric Analysis.* Prentice Hall.

Hill, R. C., Griffiths, W. E., Lim, G. (2008) *Principles of econometrics*. John Wiley & Sons Inc.

IRRI, (International Rice Research Institute) (1997). Annual Report 1996-97. Rice Research: the way forward. Los Banos. International Rice Research Institute, Philippines.

Kidane, H., Alemu, Z. G., Kundhlande, G. (2005) *Causes of Household Food Insecurity* in Koredegaga PA, Oromiya Zone, Ethiopia. Agrekon, Vol 44, No. 4

Krishnagopal, G.V. (2010). *Assessment of System of Rice Intensification (SRI) Programme in Bihar: Final Report*, submitted to Bihar Rural Livelihoods Promotion Society, Bihar

Kumar, R. Mahender, (2009). Research Experiences on System of Rice Intensification and Future Directions, *Journal of Rice Research*, 2009 Vol.2, No.2

Mansfeild E. (1983). Technological Change and Market Structure: An empirical study, *The American Economic Review*, 73 (2), 205-209.

McClelland, S. (2002) Indonesia's integrated pest management in rice: Successful integration of policy and education. *Environmental Practice*, 4 (4), 191-195.

Moser, Christine, M. and Barrett, Christopher, B. (2006). The complex dynamics of smallholder technology adoption: the case of SRI in Madagascar, *Agricultural Economics*, Volume 35, Issue 3, pages 373 -388, November.

Muluken, Y., Bogale, A., Negatu, W. (2008) Measuring rural household food security and it's determinants in Assosa district of the Benishangul Gumuz region, Ethiopia. *Quarterly Journal of International Agriculture*, 47, No. 4.

Padel, Susanne, (2013) Is organic farming 'innovative' enough for Europe?, *ORC Bulletin*, No. 113 - Autumn

Rogers, Everett M. (1962). *Diffusion of Innovations*, Glencoe: Free Press.

Stoneman, Paul. (1987). *The Economic Analysis of Technology Policy*. Oxford: Clarendon Press.

Stoop, W.A., Uphoff, N. and Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar; opportunities for improving farming systems for resource poor farmers. *Agric. System*. 71:249-274

Trimmer, C. Peter, (2010). The Changing Role of Rice in Asia's Food Security, Asian Development Bank, Manila, Discussion Paper No. 15, September

Tumusiime, Emmanuel, and Edmund Matotay. (2014). Agriculture sustainability, inclusive growth, and development assistance: Insights from Tanzania. *Journal of Sustainable Development* 7(4): 181-190. doi:10.5539/jsd.v7n4p181

Vidal, John (16 February 2013). India's rice revolution. *The Observer* (London: The Guardian). Retrieved 20 October 2014.

Uphoff, N. (2007). Reducing the vulnerability of rural households through agro ecological practice: Considering the System of Rice Intensification (SRI), Mondes en Développement, 35:4.

Uphoff, N. (2008). The System of Rice Intensification (SRI) as a System of Agricultural Innovation, *Jurnal Tanah dan Lingkungan*, Vol. 10 No.1, April 2008:27-40 ISSN 1410-7333

Wooldridge, Jeffrey, M (2009) *Introductory Econometrics: A Modern Approach*, 4th Edition, Cengage Learning, ISBN-10: 0324581629

END

Comparison between SRI & Conventional Rice Field (Chakai, Jamui- Bihar)

Weeding with Cono Weeder (Chakai, Jamui- Bihar)