Is the System of Rice Intensification (SRI) pro poor? Labour, Class and Technological Change in West Africa

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Abstract

CONTEXT

Increasing numbers of young people enter Sub-Saharan Africa's labour markets each year while industrial jobs only grow slowly. As 62% of Sub-Saharan Africans work in agriculture and as the rural population will continue to rise, agriculture will need to provide additional income-earning opportunities. In this context agricultural technologies should be promoted that can increase food production to answer rising demand and generate decent income-earning opportunities. The System of Rice Intensification (SRI) is widely promoted in West Africa and could address these needs – but recent findings from Asia present negative social impacts on workers.

OBJECTIVE

This paper explores the mechanisms that shape adoption patterns and impacts of SRI in different (West African) contexts through a labour lens.

METHODS

Our innovative theoretical framework integrates analytical and empirical categories from Farming Systems research and agrarian political economy. The mixed methods approach combines: (1) quantitative analysis of existing survey data from 857 agricultural households in Ghana, Benin and Mali; and (2) qualitative analysis of an in-depth case study in the Oti Region of Ghana.

RESULTS AND CONCLUSION

SRI increases yield and profitability in West African rice farming, especially when locally adapted. Farmers adjust SRI to fit lowland rice farming, where water cannot be controlled and to address labour constraints. Additional labour for transplanting (instead of broadcasting) – coinciding with an existing labour bottleneck – constrains SRI adoption. SRI is mainly practised by marginal and accumulating farmers and to a lesser extent by medium farmers. Accumulating farmers invest in agriculture, farm profit-oriented and overcome labour

constraints by hiring. Thus, they can practise SRI on larger scale and their absolute benefits are higher. Nevertheless, they rely on hired labour to do so, which strengthens workers' bargaining position. Consequently, SRI benefits all: accumulating farmers who employ as well as marginal farmers and hired labourers. Contrary to findings from Asia, SRI seems to be relatively pro-poor in West Africa.

SIGNIFICANCE

While seasonal labour use remains a key constraint to technology adoption, labour intensive technologies can also contribute to increasing income-earning opportunities. The social outcomes of technological change will be shaped by both the existing agricultural practices and the social relations in which a new technology is adopted. Our theoretical framework can inform further research and the application of existing evidence to new contexts.

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1 Introduction

Employment is a key challenge facing Sub-Saharan Africa, including rural areas. Between 2015 and 2030 375 million youth will enter the labour market in a context of limited growth of industrial jobs (Meagher, 2016; Losch, 2016). At the same time, social differentiation and commodification make it increasingly difficult to acquire the land, livestock and trees, necessary to build a livelihood in farming (Turner, 1999; Amanor, 2010). As 62% of people in Sub-Saharan Africa work in agriculture (Filmer and Fox, 2014) and the rural population will continue to grow in absolute terms, agricultural development projects will need to carefully consider their employment effects (Losch, 2016).

In this context, we assess the employment effects of an alternative rice farming technique, the system of rice intensification (SRI). According to Styger and Jenkins (2014) SRI's key principles are early and healthy plant establishment, minimizing competition between plants, increasing soil fertility and avoiding flooding and water stress. These can be achieved through adaptable practices (see table 3): Alternate wetting and drying (to avoid flooding and water stress) induces aerobic soil conditions to enhance root growth, soil microbial activity, and thus nutrient uptake (Uphoff, 2003). Transplanting young seedlings (for early and healthy plant establishment) enhances tillering capacity to over 80 instead of 8-13 tillers (Uphoff, 2003; Stoop, Uphoff and Kassam, 2002; Mishra et al., 2006). While wide spacing (for minimized competition) and non-flooding provides ideal conditions for weed growth (Moser and Barrett, 2003b; Stoop, Uphoff and Kassam, 2002), planting in widely spaced square patterns enables the use of mechanical weeders (Noltze, 2012). These mechanical weeders enhance soil aeration (Uphoff, 2003). Given its low-input nature, it is an affordable technique that frequently outperforms conventional farmers practices (Berkhout, Glover and Kuyvenhoven, 2015).

SRI has increasingly gained relevance in West Africa: It is widely promoted receiving government support in Benin, Togo, Mali and Senegal (Styger and Jenkins, 2014; SRI-Rice, 2016). The West Africa Agriculture Productivity Program (WAAPP), supported by the World Bank under the institutional umbrella of ECOWAS, claims to have achieved SRI adoption by over 50,000 farmers in 13 countries (Styger and Traóre, 2008). The 'Green Innovation Centres for the Agriculture and Food Sector' have trained ca. 25.000 farmers on SRI in 3 countries (Fett, 2019). Furthermore, in respect to transplanting SRI guidelines (seedlings younger than 21 days, carefully handling seedlings, wide spacing with at least 20x20cm and 1-3 seedlings per hill) have become mainstream recommendations in West Africa (see e.g. Rice transplanting, 2012; JIRCAS, 2012).

While SRI is often presented as 'fundamentally "pro-poor."' (Africare, Oxfam America, and WWF-ICRISAT Project, 2010; Moser and Barrett, 2003b), recent research from Asia shows that SRI adopters are not typically the poorest rural households (Taylor and Bhasme, 2019) and that SRI can negatively impact poor agricultural workers including women (Hansda, 2016; Gathorne-Hardy et al., 2016; Senthilkumar et al., 2008). Yet, although changes in the labour process are central to SRI, its impacts on hired labourers, remain understudied.

The study assesses the promotion of SRI in Benin, Ghana and Mali through the 'Green Innovation Centres for the Agriculture and Food Sector'; i.e. we assess SRI's effectiveness in real farms that use a farmer-adapted SRI, instead of SRI's efficacy (its potential under ideal conditions where all SRI principles are fully implemented). We address the following research questions in the context of West Africa focussing on lowland rice production systems:

1. How do class relations and farming systems affect SRI adoption?
2. What are the impacts of SRI on farm level?
3. What are the impacts of SRI on society level, especially on the labour market?

The study uses an innovative theoretical framework that combines analytical and empirical categories from Farming Systems research and agrarian political economy and is suitable to assess how existing agricultural practices and social relations shape adoption patterns and impacts of SRI in different contexts. While adoption studies usually see labour mainly as a constraint (Tripp and Longley, 2006), in contexts of overcrowded labour markets increased labour use can contribute to increasing income-earning opportunities (Pretty, Toulmin and Williams, 2011; Losch, 2016). Using the lens of labour relations enables us to assess the social impact of technological change beyond the farm.

As the literature on SRI concentrates heavily on irrigated farming in Asia (see SRI-Rice, 2021) and this is (to our knowledge) the first socio-economic study of SRI in West-Africa beyond farmer field trials, the research enables comparisons of results across contexts – a key theme of our discussion section.

2 Theoretical Framework

This paper adopts an agrarian systems perspective which reconciles concepts and insights from two key fields in agricultural and rural research: Farming systems research and agrarian political economy (Bainville, 2017; Cochet, 2012). Farming systems research seeks to understand farming practices and constraints of (resource-poor) farmers, with a focus on potential interventions (Chambers and Ghildyal, 1985; Collinson, 2000). Agrarian political economy investigates the *"social relations and dynamics of production and reproduction, property and power in agrarian formations and their processes"* (Bernstein and Byres, 2001). Combined, these approaches provide an in-depth understanding of technological change in agriculture.

Figure 1 presents the theoretical framework used in this study; variables used in quantitative analysis are highlighted with italics:

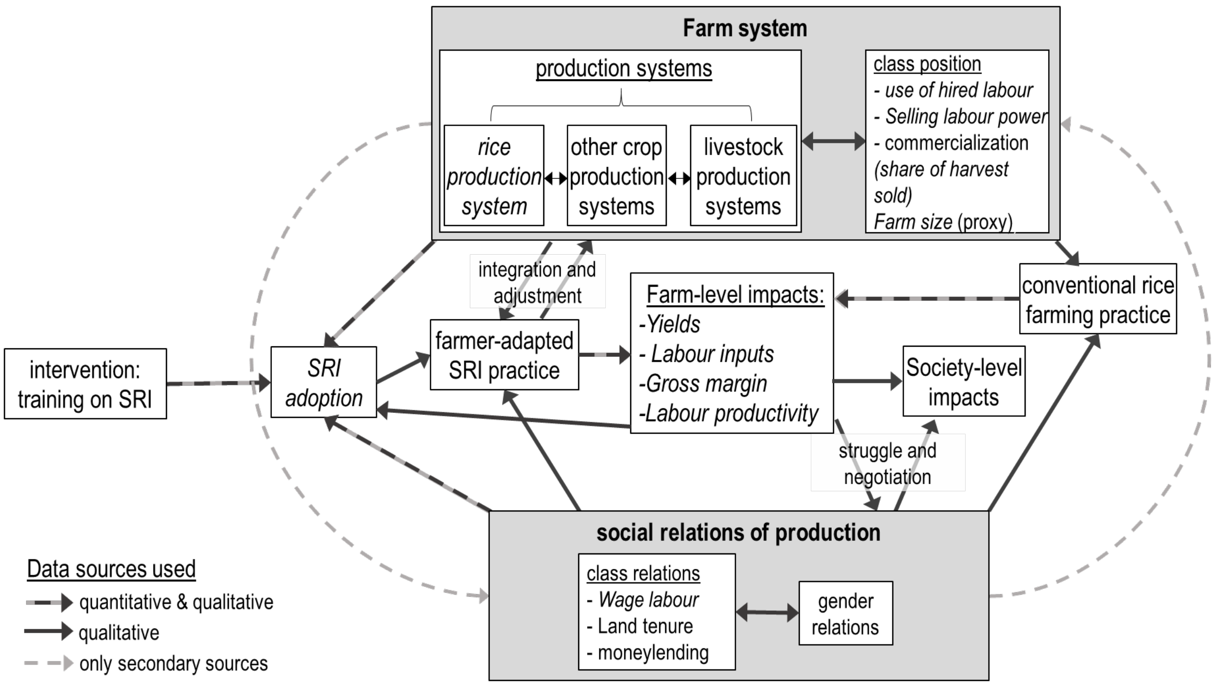

Figure 1: Conceptual framework and data sources

2.1 Concepts and definitions

2.1.1 Farm systems, farming systems and cropping systems

Following the farming systems approach, the farm itself is described as a farm system, where resources like land and labour are carefully balanced between different farming and non-farming activities. A farming system is a "*population of farm systems"* with *"broadly similar resource bases, enterprise patterns, household livelihoods and constraints*" (Dixon, Gulliver and Gibbon, 2001, Introduction (online)). A farming system often has livestock and cropping systems as subsystems. A cropping system, e.g. a rice production system, describes the cultivation of a plot, including the agro-ecological context, crop succession, farming techniques used etc. (Cochet, 2012).

2.1.2 Rural class relations

Farm systems are incorporated in a wider network of social relations, particularly as buyers and sellers of labour power. Drawing on the extensive literature on farmers' differentiation we distinguish these class positions: accumulating farmers, who produce for the market (*commercialization*), invest in farming and *hire labour* – and two classes of labour, namely marginal farmers, that operate small allotments but fundamentally depend on wage labour, as well as completely landless labourers (Lenin, 1964; Bernstein, 2010; Oya, 2004; Gyapong, 2019). In between we find 'medium farmers', closer to the classic notions of 'middle peasants' in the India literature (Patnaik, 1988; Bharadwaj, 1974), or 'petty commodity producers' as described by Bernstein (2010). These comprise households that can sustain themselves on their farm, engage in markets, and do not need to hire labour in or out. Farm systems of marginal and accumulating farmers differ, as accumulating farms face fewer capital and labour (hiring when necessary) constraints and food is not their production priority. Accumulating farms are thus characterized by more monocropping, larger fields, fewer varieties of plants and less crop-livestock interactions (Chambers and Ghildyal, 1985).

2.2 Theory of Change

2.2.1 SRI adoption

A key postulate of Farming Systems research is that farmers "*have good reasons to do what they do*" (Ruthenberg, 1971; Cochet, 2015). Farmers decisions to adopt (or not adopt) SRI thus depend on its expected utility compared to other available practices (Feder, Just and Zilberman, 1985), particularly its likelihood to be more profitable (Ghadim and Pannell, 1999).

However, this utility is situated in a given agrarian context, where given rules of access to production factors constrain the range of choice for different classes of farmers (Cochet, 2015). Understanding the mechanisms that drive farmers' adoption decisions requires a thorough assessment of the functioning of (different classes of) farming households, their resource allocation strategies, and labour relations (Andersson and D'Souza, 2014). A farmer's stance towards new technologies or crops depends on how they can be integrated into an established farm system (Swindell, 1985; White, Labarta and Leguía, 2005). Differences between farm systems of marginal and accumulating farmers (Chambers and Ghildyal, 1985), as well as differential access to resources likely leads to different adoption strategies potentially affecting status, intensity and depth of adoption (Tumusiime, 2017). We thus expect structural differences between adoption rates of different classes of farmers,.

A quantitative adoption model describes what kinds of households adopt SRI, while the resource allocation strategies that underpin this decision require using additional (qualitative) methods (Andersson and D'Souza, 2014).

2.2.2 Farmer adapted practice

When technologies are promoted as packages, as in the case of SRI, farmers may only adopt some components (Feder, Just and Zilberman, 1985). Farmers may make adaptations to SRI like adjusting the transplanting pattern to the shapes of their terraces or using herbicide instead of manual weeding to save time – adaptations not reflected by experiments comparing a standardized prescription with an equally standardized 'conventional practice' (Glover, 2011). Determining the exact practices farmers use and the rationales for these adjustments was a key component of our qualitative field work.

2.2.3 Farm level impacts

The immediate impact of technology adoption is the difference in outcome between previous and implemented practice. In our impact model (see section 4.3.2 and 4.4.2), we assess the effect on key farm-level measures, affected by SRI, namely *yields, gross margins* and *labour productivity* (Uphoff, 2003). We further assess changes in *labour use per task* to check whether changes in seasonal labour use coincide with labour bottlenecks.

2.2.4 Society-level impacts

Beyond this economic evaluation on farm level, we need to consider the wider impacts on society, as technologies tend to serve those who produce and adopt them, but may negatively impact other classes (Liodakis, 1997; Byres, 1981). As SRI fundamentally changes the labour process in rice production, we particularly focus on labour. If labour savings accrue to hired workers – as reported for SRI in India (Hansda, 2016; Gathorne-Hardy et al., 2016; Senthilkumar et al., 2008) - this has negative implications for poverty and equality, as extreme poverty is especially prevalent among agricultural workers (FAO, 2019). As most labour hiring takes place during labour bottlenecks (Swindell, 1985), the seasonal distribution of changed labour inputs is a key link to employment effects. However, agrarian change results from both external forces (like technology transfer) and class struggle (Brenner, 1976). While the farm-level effects of SRI are a first indication of potential society effects, the distribution of costs and benefits between farmers, workers and landlords needs in-depth qualitative assessment.

3 Methods

The study used mixed methods based on an observational approach. In contrast to experimental designs like randomised control trials which follow strictly pre-defined protocols (Olsen, 2019), these data reflect the adaptations farmers make to integrate SRI into their farm system (see Glover, 2011). Furthermore, we combine quantitative analysis (i.e. statistical hypothesis testing) with qualitative fieldwork (i.e. collection of unstructured interview data, in which emerging patterns are identified). This combination of methods produces complementing insights - for example when qualitative analysis identifies causal mechanisms that could explain statistical results. Additionally, it allows for methodological triangulation (see Bitsch, 2005) thus increasing robustness of study results.

3.1 Study Area

The study was conducted in 3 West-African countries, namely Benin (Alibori, Borgou, Collines and Zou department), Ghana (Ashanti, Eastern, Volta and Oti region) and Mali (Mopti, Kayes, Koulikoro, Segou and Sikasso region) (see figure S1) - spanning from 6° to 16° latitude and -12° to 4° longitude and including semi-arid, sub-humid and humid environments. The growing season in the semi arid environment is from July to October; in the sub-humid environment from April to November; and in the humid environment it lasts from March to December (Vrieling, De Leeuw and Said, 2013).

3.1.1 Rice production systems

There are three main rice production systems in West Africa: In the upland rice production system rice is cultivated on plateaus and slopes (Defoer et al., 2004). The lowland rice production system is practised in floodplains and inland valleys, using residual and water-table moisture (Global Rice Science Partnership, 2013). Lowland rice production systems are more robust than upland systems and have potential for intensification, i.e. through water control (Defoer et al., 2004). Upland and lowland rice production systems are practised in humid and sub-humid environments. Irrigated rice farming is possible in some inland valleys and along rivers, particularly the Senegal, Niger, Black Volta, Chari and Logone rivers (Global Rice Science Partnership, 2013). Water is diverted from dams and rivers or pumped from surface water or tubewells. Labour remains a major constraint and the tight cropping calendar leaves little room for delays. Thus, mechanization and direct seeding are widespread (Defoer et al., 2004). Key figures for these rice production systems are presented in the supplementary material (table S1)

3.1.2 class relations

In the region, rural households usually have multiple income sources including agriculture. While richer households diversify into high return non-farm activities, the poorest households often need to seek agricultural wage labour as a last-resort activity and accept low wages and poor labour conditions (Davis, Di Giuseppe and Zezza, 2017; De La O Campos et al., 2018). Also, households who don't belong to landholding families (and are thus perceived 'strangers') can only access land by paying rent or entering sharecropping arrangements (Turner and Moumouni, 2019; Colin, 2012). Consequently, West Africa has active agricultural labour markets where local marginal farmers, labour migrants and youth are common sellers of labour power, i.e. they are compelled to work for others, often neighbours with a wealthier class status (Oya and Pontara, 2015; Gyapong, 2020). Sharecropping was not practiced for lowland rice in the qualitative study region, but it may occur in other parts of West Africa (Delville et al., 2001). Therefore, class is here used as a concept to distinguish rural people's relative position with respect to the means of production (e.g. land, capital and inputs), their capacity to farm, and the labour market, i.e. whether they mostly hire in or out labour (Bharadwaj 1974).

3.2 Quantitative methods

3.2.1 The data set

We used a secondary dataset originally collected as a midterm survey of the Green Innovation Centres for the Agriculture and Food Sector by GFA Consulting Group GmbH in 2018 (see Sass et al., 2018); more precisely we used a subset containing all rice farming households from the countries where the project promoted SRI, i.e. Benin (Alibori, Borgou, Collines and Zou department), Ghana (Ashanti, Eastern, Volta and Oti region) and Mali (Mopti, Kayes, Koulikoro, Segou and Sikasso region). The maximum sample size per country was set at 600 and then stratified across regions (proportional to number of intervention villages) and crops targeted by the project. Within regions clustered random sampling (with the village as primary sampling unit) aimed to create a dataset representative of the target group: Only households in targeted districts producing one of the targeted crops for the market and earned income were interviewed.

Not being explicitly part of the target population agricultural labourers are underrepresented. The dominance of medium and accumulating farmers in the quantitative sample may result from the exclusion of households that produce rice for self-consumption and the use of household lists in Ghana and Mali, which is likely biased against the poorest segments of the population (Sender, 2003). However, statistical analysis focussed on describing differences between these classes rather than representative means e.g. by using a hired labour dummy. An overview of variables and descriptive statistics is presented in table S2.

Collected with the aim of calculating gross crop margins the dataset contains detailed information on the use of inputs and equipment. Family and hired labour inputs are recorded disaggregated by gender and task, which does not only offer valuable detail, but enhances data quality, as respondents don't need to provide cognitively challenging calculations of absolute labour use (see Arthi et al., 2016).

Table 1: Overview of households used for quantitative analysis

	by countries			by rice production system		Total
	Benin	**Ghana**	**Mali**	**lowland**	**irrigated**	
With SRI	51	102	144	138	159	297
Without SRI	190	155	215	346	214	560
Total	241	257	359	484	373	857

3.2.2 Modelling SRI adoption

The adoption model focusses on (self-reported) status of adoption, i.e. whether a farmer adopts (SRI=1) or not (SRI=0). More precisely, interviewees were asked "Have you adopted one or more of the following innovations since January 2016?" and could multiselect items from a list. Although we do not have more detailed information on farmers' practices in the quantitative dataset, based on our qualitative fieldwork and existing literature (see section 5.1.3) we are confident that adoption (SRI=1) refers to practising an adapted version of SRI as described in table 3.

We construct a logit model using Stata: $Y_{1i} = Logit(\alpha + \beta x_i + u_i)$ where Y_{1i} represents the probability that an household i adopts SRI and x_i represents a vector of variables determining adoption including those variables discussed in section 2.2.1, as well as other variables related to technology adoption (based on Feder, Just and Zilberman, 1985), used as controls. α and β are coefficients to be estimated.

To assess how class and farming system affect SRI adoption, the production function includes *rice productions system (lowland or irrigated)* and 3 class proxies, namely *production area*, use of *hired labour* and commercialization (*share of harvest sold*). Labour availability, including family and hired labour, is expected to be positively associated with adoption, as labour availability may constrain the adoption of SRI (Moser and Barrett, 2003b; Devi and Ponnarasi, 2009; Tumusiime, 2017) and agricultural technologies in general (Feder, Just and Zilberman, 1985; Andersson and D'Souza, 2014). Access to (hired labour) is expected to be the mechanism behind class differences in SRI adoption (Tumusiime, 2017; Taylor and Bhasme, 2019). Lastly, we control for *contact with extension* which has been positively associated with technology adoption including SRI (Birkhaeuser, Evenson and Feder, 1991; Devi and Ponnarasi, 2009; Tumusiime, 2017).

3.2.3 Estimating the impact of SRI

As we don't use experiment data, we use ordinary least squares regressions to control for potential differences between treatment and control group with regards to relevant covariates (Kurth et al., 2006). Following our theoretical framework (see section 2.2.3), we estimate the effect of SRI on labour use, i.e. the number of labour days provided by household members and hired labour for each step of production. In the model $Y_{2i} = \alpha + \beta x_i + u_i$, Y represents labour time, while x_i represents a vector of independent variables including SRI as well as a set of covariates, namely production system, relevant labour-saving technologies (e.g. tractors, herbicides, combine harvesters, etc.) and economies of scale (area under rice cultivation). As the effect of SRI could be dependent on the production system, we also include an interaction effect. To assess the profitability of SRI, we further assess its effect on yields, gross margins, and labour productivity. Yield was based on amount of harvest and area farmed, as provided by farmers; labour productivity was calculated as yield per labour time. Gross margin includes the value of product (both sold and consumed) minus variable costs for land, labour, and inputs (for details see table S2). Beyond economies of scale and production system, we control for the effect of fertilizer use on yield and labour-saving technologies (tractors, herbicides) on gross margin and labour productivity.

3.3 Qualitative methods

The qualitative data were gathered during fieldwork in the Oti Region of Ghana in July 2019 through 54 semi-structured interviews, 8 focus group discussions and direct observation. A translator, who was a Master student of Agricultural Sciences and spoke Ewe, Twi and Guan, supported organising and conducting interviews. When participants gave informed consent, interviews were audio-recorded.

3.3.1 Sampling

The funding organisation suggested a study area, where farmers practice SRI and study logistics were feasible. We combined purposive and snowball sampling to find respondents from our target groups, i.e. farmers practising SRI and people providing hired labour in rice farming. A local extension officer provided contacts of three farmers' groups, that had received training on SRI from the Ministry of Food and Agriculture[1]. Two groups farmed some land, where basic water-management structures (mounds and channels) had been constructed. We also included labourers these farmers knew or hired (snowball sampling) and sampled additional participants at rice cultivation sites. Participants found through snowball sampling or in the fields were mostly marginal farmers, while in the farmers groups accumulating farmers dominated. This allowed for an analytically relevant balanced sample, including both sides of the spectrum of farmers and workers. When 'schoolchildren' came up as a new category of workers, we decided to visit schools to interview teachers or headmasters. We refrained from interviewing minors due to ethical concerns.

3.3.2 Data collection

Semi-structured interviews investigated the lives and work experiences of labouring and non-labouring farming households and young agricultural workers. Focus group discussions with labouring or non-labouring farmers included three seasonal calendars (RUDEP, 2007) two adapted Net-Maps (see Schiffer, 2007) and three discussions of the impact of SRI. All focus-group discussions used visual recording on a flip-chart paper to help participants follow the discussion. Direct observation included frequent visits to rice fields and conversational interviews to validate farming practices and labour arrangements. Information was captured as notes and photographs.

3.3.3 Qualitative Analysis

The analysis focused on creating a causal narrative. After transcribing, sections of the interviews were coded according to research questions and evolving analytical categories. A tabular overview of households facilitated the identification of patterns. Data triangulation (Bitsch, 2005) included comparing claims from different participants and comparing interview data to observations.

[1] Sampling from farmers groups introduced a 'project bias' (see Chambers, 1979) into the research. This was intended by the funding organization interested in the effects of their project.

4 Results

4.1 SRI Adoption

4.1.1 Qualitative results

Visiting rice fields in the Oti region, we saw two alternative technologies to SRI. Firstly, transplanting ‘scatteredly’, where seedlings are transplanted without trying to achieve a specific planting pattern or uniform distance between plants. Many farmers who have adopted SRI describe this change as shifting from transplanting ‘scatteredly’ to transplanting ‘in lines’. However, when it comes to intensity of adoption, the relevant counterfactual is broadcasting, i.e. spreading seeds onto the soil manually. Only few farmers manage to transplant their whole rice plot(s). Most plant “*the little that I will be able in rows, the remaining one broadcasting”* (farmer and teacher).

In the Oti region, all classes of farmers adopt SRI. Class differences mainly apply to intensity of adoption. All of the marginal farmers asked stated they transplant all their land[2], which never exceeded ½ hectare. Only 3 (11%) farmers who hire labour said they transplant all their land. Two of them were widows, that farmed only ½ hectare of rice and ½ hectare of maize. While marginal farmers transplant a higher *percentage* of their land, those hiring labour can transplant the largest *absolute* area. As transplanting is very labour-intensive, practising SRI on a large scale usually necessitates hired labour. When asked why they don’t transplant more area 63% of farmers replied they can’t afford to hire more labourers. According to farmers, transplanting is even more costly than harvest, costing 35-50 GHS (8-12€)[3] per ’12-square’ (ca. 605 m²), the smallest local land unit. In the case study, the 7 farmers (25%) who could transplant more than ½ hectare were all classified as accumulating farmers.

Nevertheless, the area transplanted also depends on the family cycle. The abovementioned accumulating farmers had relatively large families, with 2-7 children that could help during transplanting. Therefore, they were also characterised by ‘traditional idioms of accumulation’[4] whereby success depends on their capacity to mobilise extended family labour. Moreover, some widowed medium farmers transplanted with the help of their grandchildren. Yet, those unable to hire labour for transplanting could not even transplant more than ⅓ hectare, even when their only farmland was ½ hectare of rice cultivation.

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[2] However, some were using narrower spacing.
[3] exchange rates: 1€ = 4.132 GHS = 655.957 XOF; based on December 2015 (Deutsche Bundesbank, 2016)
[4] See Cheater (1984)

4.1.2 Quantitative results

Model 1 shows the class proxy hired labour is significantly positively associated with adoption of a farmer-adapted SRI (practices are described in table 3). Furthermore, labour availability is positively associated to SRI adoption: households that hire labour or engage more family members in rice production are significantly more likely to adopt SRI. Lastly, households in the irrigated production system have a significantly higher probability of adoption.

Table 2: Logit model of SRI adoption

	(1) **SRI adoption**
Family members helping in rice production	**0.0239***
	(0.0115)
Use of hired labour [dummy]	**0.699*****
	(0.169)
Area under rice cultivation [ha]	-0.0453
	(0.0305)
Share of rice harvest sold [a]	0.531
	(0.300)
Contact to extension [dummy]	**1.488*****
	(0.312)
Lowland production system [dummy] [b]	**-0.857*****
	(0.171)
Constant	**-2.321*****
	(0.360)
Observations	856
Pseudo R-squared	0.0720
Correctly classified	67.64%

*Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05*
[a] proxy for commercialization
[b] default: irrigated production system

4.2 Farmer-adapted SRI practices

4.2.1 Qualitative results

Through direct observation and interviews with farmers, we learned which adaptations to SRI farmers have made, that better fit their circumstances than official SRI recommendations (see table 3). For example, most farmers planted 2-4 seedlings per hill (instead of 1), because "*Maybe one of the plants can die and the other one will take over*." (student and farmer). Likewise, seedlings younger than two weeks were considered too delicate to withstand strong flooding or very sunny days. Nevertheless, 2-3 week-old seedlings are younger than seedlings used by non-adopters and farmers are aware of younger seedlings' better tillering ability.

Labour is a major constraint in farming and a key factor for technology adoption. According to the seasonal calendars discussed with farmers, transplanting is done in July and August, when clearing new land, harvesting peanuts, sowing corn, planting plantain etc. already create a labour bottleneck. Farmers must finish transplanting and other tasks by late August and labourers want to finish work quickly to maximize task payments. When farmers lack the time to transplant, they broadcast. Many adaptations aimed to minimize scarce labour time, which likely affects yields. Another frequent argument against young seedlings was the time needed to carefully uproot and transplant them. A manual weeding tool introduced in one community was abandoned in favour of weedicide as farmers found it too tedious and time consuming.

Table3: SRI principles, recommendations and observed practices, based on (Styger and Jenkins, 2014), training manual and fieldwork

SRI-Principles	Recommended practices	Observed practices
Encouraging early and healthy plant establishment	Early transplanting of 8-12 day old seedlings (to encourage quick establishment and tillering)	Transplanting of 2-3 week old seedlings (that are still young but more robust)
	Careful transplanting & transplanting all seedlings the same day	Transplanting quickly (to finish before end of August (family) or to maximize task payments)
Minimizing competition between plants	Wide spacing (25x25cm) in a square pattern	Wide spacing (25x25cm or 20x20cm) in a square pattern
	Planting 1 seedling per hill.	Planting 2-3 seedlings per hill (in case one dies)
Building fertile soils, rich in organic matter	Use of compost or manure to enhance soil structure and balance nutrient supply.	Using dead weeds as green manure; use of synthetic ammonia and urea.
	Weeding with rotary hoe (to increase soil aeration and thus microbial activity)	Weed control with weedicide (to reduce workload)
Careful water-management to avoid flooding and water stress	Land preparation to level the surface (to facilitate water distribution)	Land preparation limited to spraying or clearing, land often contains stems and anthills
	keeping soils moist but not saturated by intermittent wetting and drying (to alternate aerobic and anaerobic soil conditions)	Alternate wetting and drying through dependence on rainfall.

4.3 Farm level impact: labour use

4.3.1 Qualitative results

In the Oti region, the major change in labour input concerns transplanting. According to farmers one person can broadcast ½ hectare per day, while transplanting the same area requires about 4 days with 3 persons (2 transplanting, 1 uprooting). However, compared to transplanting 'scatteredly' SRI (with farmers' adaptations) takes less time, as it uses less plants per area. Also, using ropes to mark where to transplant helps to keep focussed and not lose direction.

Farmers report that transplanting in lines simplifies tasks during other parts of the production.

> *In the scattered one, when you want to spray the rice, you will be stepping on the rice. But the one in lines, you can pass through the lines.*
>
> *(farmer and food seller)*

Also, farmers state that thanks to the lines they don't lose direction when spraying. Walking through when scaring birds is easier, too. Moreover, "*It is easy to harvest. […] When you get into a hill, you cut, you harvest.*" (young farmer). Threshing was perceived easier, as the rice grows separate from the weeds. This benefits both family members and hired labourers. As agricultural labour is remunerated by area, irrespective of planting technique, labourers can work quicker and manage more area per day, hence increasing their wages per day.

4.3.2 Quantitative results

Model 3 (table 4) shows significantly increased labour inputs for SRI during planting. Furthermore, households with larger areas under rice cultivation use significantly less days per hectare for sowing, weed control and harvest.

Table 4: Ordinary Least Squares regression on labour time in days per ha

	Labour use in:					
	(2)	(3)	(4)	(5)	(6)	(7)
	Land preparation	**Sowing/ planting**	**Weeding**	**Chemical & fertilizer application**	**Pest and disease control**	**Harvest**
	[days/ha]	[days/ha]	[days/ha]	[days/ha]	[days/ha]	[days/ha]
SRI	-1.556	**6.954***	3.293	1.005	0.184	7.022
	(2.361)	(3.089)	(2.751)	(0.781)	(4.997)	(4.159)
no SRI & lowland production system [interaction term]	-3.805	2.001	3.044	0.785	-12.38	-2.275
	(3.289)	(4.294)	(3.809)	(0.995)	(6.938)	(5.729)
Area under rice cultivation [ha]	-0.491	-0.708	**-0.941****	**-0.190***	-0.536	**-1.006***
	(0.278)	(0.364)	(0.326)	(0.0769)	(0.593)	(0.489)
Lowland production system [dummy] [a]	5.305	1.146	**-6.369***	1.551	**28.14*****	6.641

	(2.745)	(3.514)	(3.116)	(0.816)	(5.674)	(4.755)
Family members helping in rice production	-0.0796	0.0112	0.240	0.0297	**-0.731****	-0.0912
	(0.113)	(0.146)	(0.130)	(0.0375)	(0.237)	(0.206)
powertiller	-6.658					
	(4.231)					
ploughing [dummy] [b]	**-7.482*****					
	(1.669)					
herbicides [dummy]	**-6.562*****		**-5.852****			
	(1.732)		(2.005)			
tractor [dummy] [b]	-1.937	-3.656	**-6.321***	0.126		
	(2.341)	(2.952)	(2.675)	(0.655)		
fertilizer [dummy]				**2.689*****		
				(0.496)		
combine harvester [dummy] [b]						-23.93
						(13.77)
threshing machine [dummy] [b]						-23.44
						(38.64)
Yield [kg/ha]						0.00002
						(0.000474)
Constant	**22.22*****	**14.66*****	**20.47*****	0.569	**16.08*****	**24.35*****
	(2.379)	(2.389)	(2.452)	(0.638)	(3.804)	(3.657)
Observations	841	829	852	518	852	831
R-squared	0.073	0.019	0.040	0.098	0.079	0.027

*Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05*
A day is assumed to be 8 hours, longer and shorter days were adjusted accordingly.
[a] default: irrigated production system
[b] dummies refer to use, not ownership of equipment

While households practicing SRI under the irrigated production system had a higher median labour use than non-SRI households in our sample (see figure 6)[5], this effect was not significant in the regression analysis (model 4).

[5] This would be plausible, as weed suppression through continuous flooding is only practised by non-adopters in the irrigated production system.

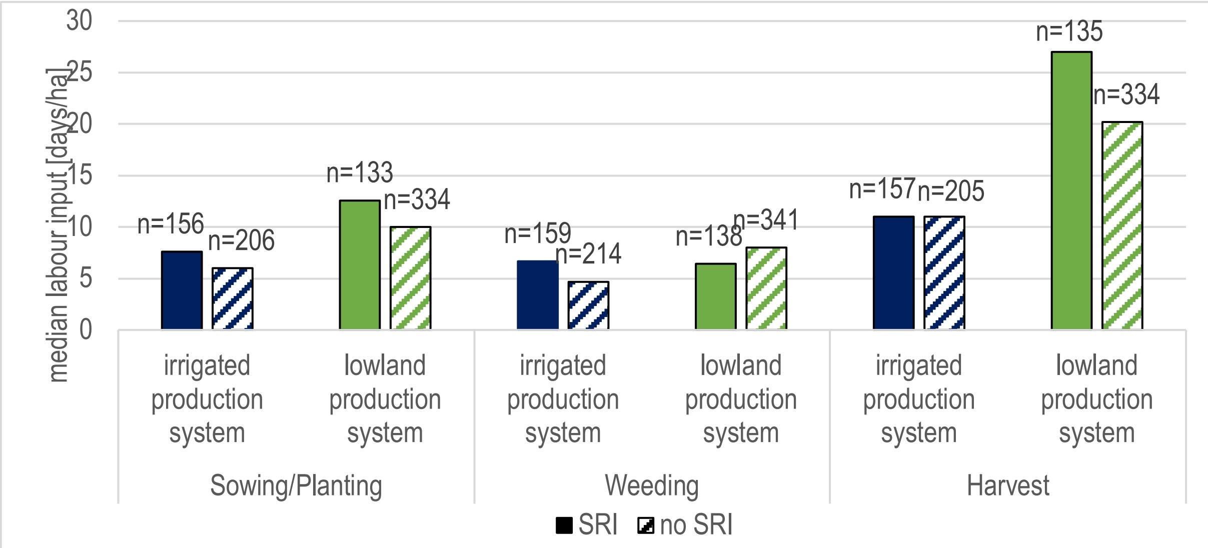

Figure 2: median labour inputs in hours for SRI adopters and non-adopters in different tasks in rice production by production system

4.4 Farm level impact: Profitability

4.4.1 Qualitative evidence

Farmers consider SRI to have clear economic advantages. Farmers report a 1-1.5 bag yield difference per ‘12-square’ (ca. 605m²) compared to broadcasting. As they can sell each bag for 300 GHS (73€), this outweighs labour costs, which are 35-50 GHS (8-12€) per ‘12-square’. Although seed savings are substantial, only 2 participants mentioned it as a benefit of SRI. Transplanting according to SRI dimensions is also more profitable than ‘scatteredly’ due to higher yields. As wages are based on area, costs for hired labour stay the same, while hours worked decrease.

4.4.2 Quantitative evidence

According to models 8-11 SRI has a significant positive effect on yields, gross margin and labour productivity, when controlling for production system, area under rice cultivation and labour-saving technologies (herbicides and tractors).

Table 5: Ordinary Least Squares regression on yield, gross margin and labour productivity

	(8)	(9)	(10)	(11)
	Yield	**Gross margin [€/ha]** [a]		**Labour productivity**
	[kg/ha]	Without cost of family labour	With cost of family labour	[kg/day]
SRI	**666.2****	**263.8****	**224.3***	**96.25***

	(207.0)	(97.45)	(102.4)	(38.87)
Area under rice cultivation [ha]	**-90.46****	-35.99	-14.18	**17.54****
	(31.92)	(20.18)	(21.21)	(6.115)
Lowland production system [dummy] [c]	**-1,178*****	**-962.4*****	**-1,109*****	-36.85
	(204.2)	(100.4)	(105.5)	(38.45)
Tractor [dummy] [b]	-277.5	-50.86	-5.313	**140.4***
	(283.7)	(133.4)	(140.1)	(54.82)
Fertilizer [dummy]	**1,011*****			
	(211.9)			
Herbicides [dummy]		55.66	-121.2	20.50
		(104.4)	(109.7)	(41.02)
Constant	**3,395*****	**1,512*****	**1,446*****	66.44
	(239.2)	(122.5)	(128.7)	(44.25)
Observations	853	771	771	853
R-squared	0.106	0.129	0.151	0.031

*Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05*
[a] *exchange rates: 1€ = 4.132 GHS = 655.957 XOF*
[b] *dummies refer to use, not ownership of equipment;*
[c] *default: irrigated production system*

4.5 Society-level impact

4.5.1 Qualitative results

Beyond the direct economic impact on individual farms, SRI has positive society level impacts through the labour market. Firstly, workers have reported increased opportunities for work, as the area transplanted has expanded, after SRI adoption made transplanting more profitable. While some of the extra work is done by family members, much accrues to hired labour. Also, as farmers spend more time transplanting, some now hire more workers for tasks that are urgent in other crops, e.g. harvesting peanuts.

Secondly, SRI is considered to make work faster compared to transplanting ‘scatteredly’. Labour is usually remunerated per task, normally in relation to area worked on. Transplanting, which is considered quite tedious as it causes waist and back pains, was done mostly but not exclusively by groups of men in some towns and groups of women in others[6]. When workers finish a task more quickly, they can earn more per day and move to a different employer the following day.

[6] Given the diversity of household models encountered – from women farming completely independently from their husbands and a Muslim farmer who claims his wives don’t ‘work’ (but sometimes ‘help’ on the farm) – a gendered analysis of SRI is not feasible within this study.

5 Discussion

Given, there are no comparable socio-economic studies on SRI in West-Africa (see SRI-Rice, 2021), the discussion follows a two-step approach. For each research question we first check whether our findings can be plausibly generalized to West-Africa. Then we discuss the findings against existing evidence obtained in Asian contexts[7]. Doing so, one needs to keep in mind that the counterfactual ‘common practice’ in these contexts will differ: Reviews of SRI in Asia usually assume a more intensive ‘conventional practice’ with continuous irrigation and densely transplanted rows with 3-6 seedlings per hill, that are 3-4 weeks old (see e.g. Uphoff, 2003; Africare, Oxfam America, and WWF-ICRISAT Project, 2010). In West Africa, however, broadcasting is widespread (Nayar, 2010) and irrigation rarely available (Global Rice Science Partnership, 2013).

5.1 How do class and farming systems affect SRI adoption?

5.1.1 As SRI exacerbates existing labour bottlenecks, access to hired labour is a key factor for SRI adoption

Seasonal labour availability considerably constrains SRI adoption, as it exacerbates existing labour bottlenecks: The planting season is the major bottleneck in farming systems of humid and sub-humid areas (Spencer and Byerlee, 1976; Karimu and Richards, 1980), where most upland and lowland rice production systems are located (Global Rice Science Partnership, 2013). We found increased labour during planting (see section 4.2 and model 3). While we did not find a significant effect on labour use in weeding, farmer field trials (Styger et al., 2011; Krupnik et al., 2012) in irrigated rice production in West Africa did. The first weeding presents a major bottleneck in farming systems in the semi-arid Sahel (Kremer and Lock, 1993; Kevane, 1994; Abdoulaye and Lowenberg-DeBoer, 2000), where much of West-Africa’s irrigated rice farming is located (Global Rice Science Partnership, 2013). While our results don’t strengthen this existing evidence, it is plausible SRI could also exacerbate this labour bottleneck where a shift to alternate wetting and drying has the trade-off of abandoning weed suppression by flooding (Stoop, Uphoff and Kassam, 2002). Consequently, the ability to engage hired labour is crucial for practising SRI on a large scale. In this study farmers transplanting more than ½ hectare were all accumulating farmers relying on hired labour. Access to hired labour significantly affects status (model 1) and acreage of SRI adoption, meaning that the class of accumulating farmers (see section 3.1.2) is more likely to adopt. Thus, even labour intensification can fail to be resource neutral (see Bernstein, 1992; Byres 1981).

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[7] For clarity, we mostly omitted work conducted in sub-Saharan Africa, namely Kenya (Mati et al., 2011; Ndiiri et al., 2013), Madagascar (Moser and Barrett, 2002, 2003a; b) and Tanzania (Katambara et al., 2013; Tumusiime, 2017). This does not change the overall conclusion.

Studies conducted in Asia found similar links between hired labour and SRI adoption: Lack of skilled labour is reported a major reason for non-adoption (Devi and Ponnarasi, 2009), dis-adoption (Alagesan and Badhar, 2009; Taylor and Bhasme, 2019) and a difficulty faced by adopters (Narbaria et al., 2015; Kumari and Singh, 2016).

5.1.2 Marginal farmers adopt SRI with difficulty and on smaller scale.

Generally, SRI is suitable for the class of marginal farmers. Logically, land intensifying technologies favour those who are land-constrained. In this study, marginal farmers transplanted their entire small rice plots (see section 4.1.1). Furthermore, farms with smaller area of rice cultivation tend to use labour more intensively for weed control, chemical and fertilizer application, and harvesting (see model 4, 5 and 7 in table 4), even when controlling for mechanization. This can indicate readiness and more capacity for 'self-exploitation' through more application of labour, in order to achieve basic production and income targets (Kautsky, 1899; Bharadwaj, 1974). Adoption by marginal farmers has also been documented in Asia, e.g. by households who do agricultural wage-labour (Noltze, 2012), or in the bottom poverty tercile (Namara, Weligamage and Barker, 2003).

However, existing literature highlights two mechanisms which constrain marginal farmers' SRI adoption. Firstly, marginal farmers may be more labour-constraint. Moser and Barrett (2003a) report that marginal farmers in Madagascar are unlikely to adopt SRI, as they face a seasonal labour constraint when immediate wage income is crucial to meet subsistence needs (Moser and Barrett, 2003b). Secondly, SRI comes with risks that accumulating farmers can manoeuvre better: SRI does not only increase yield variability (Barrett et al., 2004), it is also time-sensitive regarding water and labour inputs: Compared to maintaining a water buffer through flooding, alternate wetting and drying necessitates secure and timely access to irrigation water, thus poorer farmers (Taylor and Bhasme, 2019) and those at the tails of the irrigation system (Namara, Weligamage and Barker, 2003) are less likely to adopt. Wealthy and well-connected accumulating farmers may also be better able to access labour in time (Hansda, 2017; Taylor and Bhasme, 2019).

5.1.3 Labour use shapes farmer adaptations in West Africa

Although diverging from standard SRI recommendations, the practices observed in this study (table 3) can be considered common farmer-adaptations, as they are in line with adaptation developed through participatory farmer field trials. In response to constraints in irrigated production systems in the Senegal River Valley (Sahel) Krupnik et al. (2012) and participating farmers addressed seedling mortality risk by using 2-3 seedlings per hill that were 17-19 days old (instead of single, 14–15 day old seedling). Labour requirements for weeding were reduced by only applying alternate wetting and drying during the late vegetative stage and by spot application of herbicides. Other studies found it challenging to apply organic matter (Harding et al., 2017). Alternate wetting and drying can be limited where farmers prefer flooding fields given unreliable water supply (Krupnik et al., 2012; Styger et al., 2011) or lack water control structures thus relying on seasonal flooding (Harding et al., 2017).

5.2 What are the impacts of SRI on farm level?

5.2.1 SRI improves yields, profitability, and labour productivity

Model 8 shows that SRI is significantly associated with higher yields. This is in line with evidence from farmer field experiments in irrigated (Styger et al., 2011; Krupnik et al., 2012; Dzomeku, Sowley and Yussif, 2016) and mangrove production systems (Harding et al., 2017) in West Africa. Studies from Asia also find increases in yields (see review by Berkhout, Glover and Kuyvenhoven, 2015) both in lowland (e.g. Kabir and Uphoff, 2007) and irrigated rice production systems (e.g. Gathorne-Hardy et al., 2016).

Model 9 and 10 show a significantly higher gross margin, controlling for production system and labour saving technologies – irrespective whether a cost of family labour is included. Seed savings are substantial, when compared to broadcasting, yet labour seemed more relevant to farmers in this study. Water-savings are only relevant in a small irrigated area (Global Rice Science Partnership, 2013) and might be hampered by weak institutions (Krupnik et al., 2012). When included in trials, farmer-adapted practices were more profitable than pure SRI recommendations (Krupnik et al., 2012). Similarly, research from Asia finds SRI is more profitable than conventional practices in lowland (Kabir and Uphoff, 2007) and irrigated rice production (e.g. Ly et al., 2012; Gathorne-Hardy et al., 2016) based on both yield increases and cost-savings for hired labour, fertilizers and seed.

Model 11 shows SRI is associated with significantly higher labour productivity, controlling for labour saving technologies and production system. This corresponds to the finding that farmers find SRI profitable enough to hire external labour (section 4.1.1). In West Africa, Styger et al. (2011) also report a positive effect on profit when all labour is fully priced. In contrast, literature on labour productivity in Asia is mixed (see review by Berkhout, Glover and Kuyvenhoven, 2015), in line with heterogeneous effects on labour time (see section 5.1.1).

Given that accumulating farmers tend to adopt SRI on larger scale (see section 5.1.1. and 5.1.2), they derive higher absolute benefits from yield increases under SRI.

5.2.2 SRI's impact on labour use depends on counterfactual practices

Promoted and counterfactual practices determine how SRI affects labour inputs for different production steps - and thus labour availability during labour bottlenecks. In the Oti region, we found two counterfactual practices to SRI - broadcasting and transplanting 'scatteredly' - with shifts from broadcasting to transplanting according to SRI driving increased labour use (section 4.3.1) – a mechanism also reported in Asia (Ly et al., 2012). Where SRI means transplanting less seedlings, researchers have documented labour savings (Sinha and Talati, 2007; Gathorne-Hardy et al., 2016) as when SRI replaced scattered transplanting in our study. Such difference in counterfactual practice also explains the heterogeneity of evidence on labour effects of SRI in Asia. Nevertheless, there is a clear trend that SRI increases labour inputs in West Africa (see section 5.2), whereas in Asia results are more diverse.

5.3 What are the impacts of SRI on society level, especially on the labour market?

5.3.1 SRI has positive employment effects in West Africa, contrary to secondary evidence from Asia

An important implication for poverty reduction is the employment-creation effect of SRI in West Africa, given the increased labour use (section 4.3.: Styger et al., 2011; Krupnik et al., 2012). A key source of additional labour demand comes from accumulating farmers, who farm bigger farms and rely mainly on hired labourers when adopting SRI. Our results outline that much of the additional labour is done by hired workers. This may strengthen labourers bargaining position vis-à-vis employers and create new income earning opportunities, including for those not or hardly involved in agriculture like the student labourers in this study. The effects of labour market tightening are crucial for understanding the linkages between casual/seasonal wages and poverty dynamics in such settings, as evidence in India also suggests (Sen and Ghosh, 1993; Oya and Pontara, 2015).

Agriculture in Sub-Saharan Africa can considerably contribute to providing much needed income-generation opportunities: There are still substantial yield gaps – e.g. only 20% of estimated yield potential for maize is realized (Deininger and Byerlee, 2011) – and low agricultural labour productivity (Diao, McMillan and Wangwe, 2018). Positive employment effects accrue to labour-intensive practices like irrigated vegetable farming (Dittoh, Bhattarai and Akuriba, 2013) and digging zaï or tassa planting pits (Di Prima, Hassane and Reij, 2012; Pretty, Toulmin and Williams, 2011). The seasonal distribution of additional labour affects the social impact of technological change. If additional labour is needed during peak season, as with SRI in West Africa, hired workers will do much of the work. When additional work is needed in less busy periods, family labour can be used (Kerr et al., 2019). Yet, large labour inputs like digging planting pits, may still be done using hired labour (Di Prima, Hassane and Reij, 2012; Pretty, Toulmin and Williams, 2011).

This positive outlook stands in stark contrast to negative employment effects reported in Asia: Gathorne-Hardy et al. (2016) report that SRI-adopters hire 45% less labour, reducing wages paid per hectare by 50%. Also, households may shift away from hired labour in order to ensure careful transplanting (Ly et al., 2012) particularly when hired labourers are not trained (Noltze, 2012, p.37). Such effects seem unlikely in the West African context. As this additional labour coincides with the peak season practising SRI on a large scale cannot be done without hiring labour. Even where transplanting is done by family members to ensure careful handling of seedlings, labour may be hired for other crops instead. The gendered impacts of SRI in West Africa still need further study.

6 Conclusion

In the context of the African employment challenge, we have assessed the potential of a labour-intensive agricultural technology, namely SRI, to contribute to employment creation based on an innovative theoretical framework. In West African rice farming SRI increases yields and profitability and can be beneficial for both marginal and accumulating farmers, although in different ways and at different scale of gains. Marginal farmers can better utilize their little land through SRI and increase yields, but absolute gains are not enough to prevent them from having to sell their labour power. Meanwhile, given that additional labour is needed during seasons that are already labour bottlenecks, only accumulating farmers who can overcome labour constraints by hiring new workers for more time, practice SRI on a larger scale, and therefore achieve yields that significantly contribute to surplus growth. Thus, their absolute benefits are higher. Nevertheless, it is important to link their differentiated impacts through the lens of labour relations. Accumulating farmers rely on the labour of marginal farmers or landless workers to do so, so SRI resulting in additional labour demand contributes to the tightening of local labour markets and strengthening of workers' bargaining power. Thus, in contrast to many critical findings on SRI in Asia it seems to be relatively pro-poor in West Africa, once we consider the labour demand effects of SRI adoption. While seasonal labour use remains a key constraint to technology adoption, labour intensive technologies can contribute to increasing income-earning opportunities. The social outcomes of technological change will be shaped by both, the seasonal timing of labour inputs and the social relations in which a new technology is adopted.

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