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The use of System of Rice Intensification (SRI) near Maromizaha Protected Area, Madagascar

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ABSTRACT
Rice agriculture is key to food security in Madagascar, yet land conversion for traditional rice growing, or *tavy*, exerts significant deforestation pressures. A method known as System of Rice Intensification (SRI), has been promoted by development and conservation groups near Maromizaha Protected Area in Madagascar on the premise that it is more sustainable than traditional rice-growing practices. Although the aim of promoting SRI in the region has been to reduce deforestation pressures, preliminary observations suggest that SRI has not been widely adopted. Household surveys and observations were conducted in the communities surrounding Maromizaha Forest to assess the use of SRI, and to inform future decisions on SRI training and other approaches. Results reveal that SRI has not been widely adopted despite familiarity and generally positive perceptions of the method's usefulness. Various issues with SRI adoption near Maromizaha include disparities in access to training, the number of people per household available to participate in farming tasks, and the amount of land appropriate for implementation of SRI. We highlight questions surrounding SRI's perceived impacts upon rice yield and to explore locally-informed sustainable agricultural alternatives to both traditional rice growing practices and SRI to reduce deforestation pressures in the Maromizaha area.

RÉSUMÉ
L'agriculture rizicole est la clé de la sécurité alimentaire à Madagascar en même temps que la conversion de terres pour l'agriculture traditionnelle sous la forme de *tavy* est une source de déforestation. Des méthodes d'intensification agricole ont été proposées par des groupes de développement et de conservation. Une de ces méthodes, le Système de Riziculture Intensive (SRI), a été encouragée dans le site d'étude de l'Aire protégée de Maromizaha sur le principe d'une plus grande viabilité par rapport aux pratiques traditionnelles de la riziculture. Si la promotion de l'SRI dans la région était motivée par une réduction des pressions de déforestation, des indications préliminaires suggèrent que le SRI n'a pas été largement adopté. Des enquêtes auprès des ménages et des observations ont été menées auprès des communautés riveraines de la forêt de Maromizaha afin de comprendre les choix des intéressés afin de mieux orienter les futures décisions sur la formation à dispenser pour l'SRI et d'autres approches. Les résultats révèlent que le SRI n'a pas été largement adopté malgré la familiarité et des perceptions généralement positives de l'utilité de la méthode. Divers obstacles à l'adoption du SRI autour de Maromizaha comprennent les disparités dans l'accès à la formation, le nombre de personnes par ménage disponibles pour participer aux tâches agricoles et la quantité de terres appropriées pour la mise en œuvre du SRI. Les questions relatives aux impacts perçus du SRI sur la production de riz sont exposées et mises en contexte avec des alternatives agricoles durables aux pratiques traditionnelles de la culture du riz connues localement et au SRI afin de réduire les pressions de la déforestation dans la région de Maromizaha.

INTRODUCTION
Madagascar is an economically developing nation that ranks fifth among the 25 poorest nations of the world, with at least 71.5% of the population living in poverty (Jahan et al. 2016, World Food Programme 2016, Raveloharison 2017). It ranks 4th highest of 119 countries scored for hunger risk, with 42.3% of the population undernourished (von Grebmer et al. 2017). Among the 10 countries most vulnerable to food security impacts from natural disasters, local conditions are exacerbated by both local and global climate change (World Food Programme 2016). This vulnerability is exemplified by combined effects of a prolonged drought in 2015 into 2016 (Ibrahima and Rakotonirainy 2016, World Food Programme 2016), followed by Cyclone Enawo in February 2017, resulting in increased food prices, and intense erosion in areas lacking ground cover. Much of the island's population depends on smallholder subsistence agriculture, with rice constituting a culturally significant and vital food staple for much of Madagascar's population. As such, food security in Madagascar depends largely on effective and sustainable rice farming (Minten and Barrett 2008, Rist et al. 2014).

Notably, Madagascar also exhibits remarkable levels of biodiversity, with about 85% of species endemic to the island (Goodman and Benstead 2005). This has served as a driver of revenue for Madagascar's economy; indeed, 16.2% of Madagascar's GDP derives from tourism (total contribution – World Travel and Tourism

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Council 2018). Since most of Madagascar's unique and charismatic species depend on forested habitats, effective forest management is key for biodiversity conservation (Goodman and Benstead 2005, Schwitzer et al. 2013, Waeber et al. 2015). Forest management also positively impacts human livelihoods due to the ecosystem services that forests provide, for example, in slowing soil erosion, cycling nutrients, influencing local climate conditions such as rainfall, and providing habitat for pollinators and/or pest predators (Costanza et al. 1997, Thrupp 2000, Toledo and Burlingame 2006, Karp et al. 2013, Mahmood et al. 2014). As such, habitat degradation threatens not only biodiversity, but also the future of agricultural productivity.

TRADITIONAL *TAVY* RICE AGRICULTURE. A slash-and-burn agricultural practice known in Malagasy as *tavy* (see Box 1) has been blamed for accelerated deforestation throughout Madagascar along with similar slash-and-burn practices in other tropical forest zones of the world (Geist and Lambin 2002, McConnell et al. 2004, Schwitzer et al. 2013, Brimont et al. 2015). Yet *tavy* holds great cultural and historical significance in Madagascar, as well as it being labor-efficient, requiring few inputs, and being potentially less prone to cyclone damage—all important considerations for resource-poor farmers (Raik 2007, Pollini 2010, Froger and Méral 2012, Desbureaux and Brimont 2015). The narrative of *tavy* as the primary driver of Madagascar's deforestation is debated, particularly in comparison to large-scale extractive industries now and during colonial times (Jarosz 1996, Kull 2000, Pollini 2010, Scales 2012). However, at present, factors such as movement toward permanent infrastructure, land-use restrictions, and increasing population densities have caused an increase in pressure on available land (Pollini 2010, Brimont et al. 2015). This makes slash-and-burn agriculture a proximate cause of deforestation, though it is important to remember that the ultimate causes are complex, global in scale, and largely beyond the control of individual smallholder farmers (Jarosz 1996, Pollini 2010). Nevertheless, tensions exist regarding agricultural practices in and around remaining forest resources (Ratsimbazafy et al. 2014, Brimont et al. 2015). One place where such tensions are particularly felt is in the communities surrounding Maromizaha Protected Area in eastern Madagascar, serving to focus the geographic scope of this study.

SYSTEM OF RICE INTENSIFICATION (SRI). In efforts to ensure reliable access to food in harmony with biodiversity conservation in places like Maromizaha, various agricultural techniques have been introduced with the aim of minimizing deforestation pressures (Moser and Barrett 2003, Serpantié and Rakotondramanana 2014, Brimont et al. 2015). In particular, a method called System of Rice Intensification —SRI (Uphoff 2007) has been promoted as a sustainable alternative to *tavy* to increase rice yield and relieve deforestation pressures (Stoop et al. 2002, Moser and Barrett 2003, Brimont et al. 2015). Yet the SRI technique is meant to be used as an improvement to rice paddy agriculture that typically occurs in the lowlands and is quite different from *tavy* which is usually practiced on hillsides (Box 1). As such, a false dichotomy exists

Comparing Rice Agriculture Techniques

Rice agriculture in Madagascar can either be rain-fed or irrigated. Rain-fed rice agriculture typically occurs on hillsides utilizing a rotating plot system, whereas irrigated forms of rice agriculture occur in flat or terraced areas of land that are consistently farmed each year.

Tavy

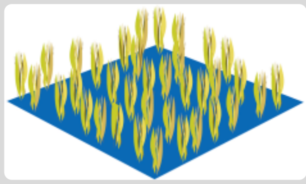
Tavy is a traditional method of rain-fed, hillside rice agriculture that involves cutting and burning vegetation prior to sowing rice seeds. *Tavy* plots are typically used for one or two years and then left to lie fallow for a time, as new areas are burned and added to the rotation (McConnell et al. 2004, Styger et al. 2009). Traditionally, these new areas would be forested. However, *tavy* encroachment upon protected forest areas is now banned in Madagascar (National Assembly of the Republic of Madagascar 2015). Though use of fire is discouraged, farmers are permitted to continue *tavy* in designated areas of previously cultivated fallow land known as *savoka*. Many farmers do not have sufficient plots to allow for adequately long (8-15 years or more) fallow periods between rotations, hence soil quality and agricultural productivity in many locales is decreasing (McConnell et al. 2004, Styger et al. 2009, Brimont et al. 2015, Desbureaux and Brimont 2015).

Conventional Paddy

Conventional paddy rice agriculture occurs in permanent lowland or terraced fields. The soil is tilled each year before planting. It is typically flooded throughout the course of the rice growing season, so it requires some level of water management and irrigation. The continuous flooding is said to aid in weed management. Seeds are sprouted in a small corner of a rice field and allowed to grow for 20-60 days before being transplanted. Farmers using this method typically plant two or three seedlings (*ketsa*) together in a bunch, estimating the space between bunches with their eyes or hands. The seedlings in this type of agriculture are not planted in a line, but are rather scattered throughout the field (*saritaka*) wherever there is space (Glover 2011, Berkhout et al. 2015).

SRA

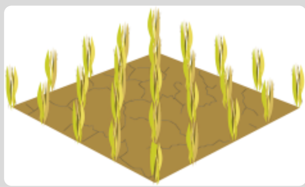
Improved Rice System or Système de Riziculture Améliorée (SRA) is an improvement upon conventional paddy agriculture that encourages uni-directional rows (as opposed to a grid) and external inputs such as fertilizer (either organic or inorganic). SRA may also include use of mechanical weeding tools and improved rice varieties (Glover 2011, Serpantié and Rakondramanana 2014).



SRI

System of Rice Intensification (SRI) is an irrigated, lowland, permanent method of rice agriculture developed in the Madagascar highlands in the 1970s and 80s (Stoop et al. 2002, Glover 2011). SRI comprises a set of practices related to the timing and placement of rice seedlings to increase yield productivity. Practices include carefully raising seedlings in a nursery, transplanting seedlings at 8-15 days, transplanting single seedlings in a 25cm grid pattern, and alternating dry periods in order to better aerate the soil. Farmers sometimes use a mechanical rotary weeder and apply organic fertilizer when possible (Uphoff 2007, Glover 2011).

Proponents of SRI see it as a sustainable alternative to conventional methods of rice agriculture, given that increases in productivity require low external inputs (Stoop et al. 2002, Uphoff 2008). Since SRI aims to intensify yields on existing plots (in contrast with the plot rotations typically associated with *tavy*), SRI is viewed as a sustainable strategy to reduce deforestation and habitat degradation pressures (Moser and Barrett 2003). However, more research is needed in different types of habitats to test the assumption that this method of rice intensification can be sustainable in the long term, in the context of broader debates related to the long-term implications of land-sparing versus land-sharing (Perfecto and Vandermeer 2010, Phalan et al. 2011).



in much of the literature regarding the promotion of SRI, where it is purported as an alternative to *tavy*. An initial hypothesis in the promotion of SRI was that intensifying lowland production would reduce clearing on upland slopes (Brimont et al. 2015). However, the promotion of an intensified lowland technique to farmers who are doing upland slash-and-burn agriculture rests on many assumptions and skips quite a few steps. In order to successfully adopt SRI, it is reasonable to assume that a farmer would first need a lowland rice field, and second, time and labor resources necessary to carry out the core practices that SRI encompasses, since SRI requires different labor inputs than does *tavy* (Stoop et al. 2002, Moser and Barrett 2003, Box 1). Despite targeted SRI training efforts over the past decade in and around Maromizaha, no study to date has documented empirical evidence on the productivity of SRI nor its adoption in the region (Glover 2011, Berkhout et al. 2015). Studies in the area have focused on fallow succession in *tavy* systems (Styger et al. 2007, Styger et al. 2009), and a study on SRI adoption was conducted in two other regions of Madagascar in 2003 (Moser and Barrett 2003). Those authors found high rates of disadoption of SRI in the areas they studied, and noted that poor farmers were less likely to adopt the technique. Moreover, Moser and Barrett noted that the promotion of SRI in rural Madagascar may contribute to income inequality. Over a decade has passed since that study, and SRI is still being widely promoted in the region of interest. As such, additional research is needed on whether farmers find SRI to be a worthwhile and practical endeavor at present, and the circumstances that influence this assessment, such as differential access to training in the method.

For at least a decade, discussion of "evidence-based conservation" has emphasized the importance of considering data in conservation decision-making practices (Sutherland and Wordley 2017, Petrovan et al. 2018). Presently, the lack of evidence on environmental and social contexts of SRI adoption makes it difficult to determine whether it is wise for development organizations to continue promoting SRI to optimize food security and biodiversity conservation at Maromizaha. This study explores SRI training, adoption, and perceptions of efficacy in and around Maromizaha Protected Area – a step toward better informing food security and conservation efforts.

METHODS

STUDY AREA. One of Madagascar's largest remaining contiguous humid forests, the Ankeniheny-Zahamena Corridor (CAZ), is located in the mountainous region of eastern Madagascar. The CAZ provides habitats for a myriad of plant and animal species, and because forest fragmentation threatens biodiversity, maintaining the contiguity of the CAZ is imperative to conservation goals (Turner and Corlett 1996, Schwitzer et al. 2013). Located at the southernmost tip of the CAZ is Maromizaha Protected Area (Figure 1), a 1880 hectare protected area ranging in elevation between 794m and 1224m (Ramanahadray 2009). Maromizaha provides habitat for at least 13 species of endangered lemurs alongside hundreds of other unique species of animals and plants, and is among the few places where two of the highest conservation-priority lemur species, *Indri indri* and *Propithecus diadema*, live in sympatry (Table 1, Portela et al. 2012, Schwitzer et al. 2013, GERP 2015b). Maromizaha Protected Area is presently managed by Groupe d'Étude et de Recherche sur les Primates de Madagascar (GERP), a non-profit primate research organization. In 2015, a total of 1257 people were reported to live in the villages surrounding

Table 1. Summary of recorded biodiversity in Maromizaha Forest (numbers are minimum number of species based on Schwitzer et al. 2013, GERP 2015b, GERP 2016).

Maromizaha forest biodiversity	
Vascular plants	433 species
Moths and butterflies	800 species
Beetles	400 species
Birds	77 species
Amphibians	60 species
Reptiles	20 species
Non-primate mammals	30 species
Lemurs	13 species

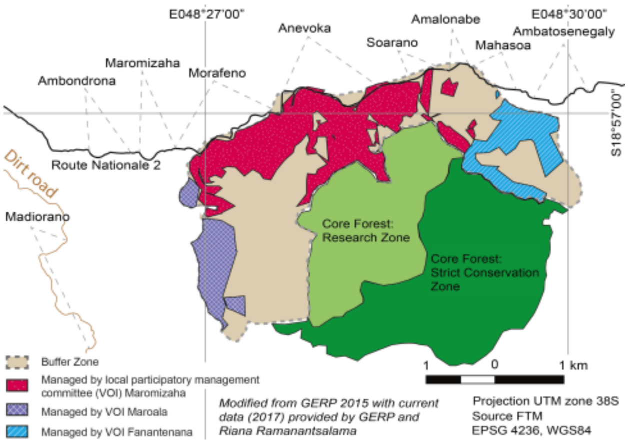


Figure 1. Map of Maromizaha Forest showing various zones of use. (Modified from GERP 2015b)

Maromizaha Forest (Figure 1), many of whom are farmers (Randrianarison et al. 2015, Surrans 2015). In this area, *tavy* has been cited as a primary driver of deforestation, and is forbidden in the forest and protected area but still occurs in fallow lands and non-protected forested areas. Notably, fallow periods in the area have decreased in the recent past due to human expansion pressures and land availability (Pollini 2010, Styger et al. 2009, Ratsimbazafy et al. 2014, GERP 2015a,b, Brimont et al. 2015).

Over the last decade, SRI has been promoted around Maromizaha by a number of development organizations, including the Peace Corps (Uphoff 2008, GERP 2015a). Promotional efforts include training sessions and the development of a Peace Corps SRI demonstration field in the village of Anevoka. Preliminary observations in 2015 suggested uneven adoption of SRI by community members, with the demonstration field underutilized by 2016. For these reasons, Maromizaha Protected Area can serve as a pilot location to explore knowledge and perceptions about SRI.

STUDY DESIGN. We anticipated that uneven adoption of SRI in the Maromizaha region may reflect either that not all people were familiar with SRI, or that not everyone familiar with SRI adopted its methods. To test among these possibilities, we used surveys to evaluate awareness about SRI in the Maromizaha community, together with the extent to which SRI techniques have been tried and adopted, tried and abandoned, or not tried at all. To provide more context surrounding familiarity, we also assessed the level of SRI training received and recorded the village of residence as it pertains to proximity to training resources. We predicted higher SRI use among farmers who had received formal training and who reside in close proximity to training and resources.

A decision not to use SRI may reflect that SRI is not considered an effective means of increasing rice yields. To test this hypothesis, we asked farmers whether they perceived an overall yield increase in fields where SRI was used. We asked farmers not using SRI a series of questions about their rice farming techniques, including whether they continued to use *tavy*. Because SRI is thought to be more labor-intensive than *tavy* (Moser and Barrett 2003), we asked how many people helped with farming in each household to provide insight into labor availability in relation to SRI adoption. We predicted that families with fewer labor resources would be less likely to have adopted SRI.

SURVEY METHODS. Household survey questionnaires were conducted between June and August of 2016, recruiting one adult (18 years of age or older) representative to survey from as many households as possible in all nine villages. Participants were engaged opportunistically in village settings, and via purposive snowball sampling in areas that were more difficult to access. All data collection described herein was reviewed and approved by the Institutional Review Board at Ohio University (IRB 16-X-58), with permissions in Madagascar obtained through the official offices GERP and MICET. Approved consent forms were used in the recruitment of participants, participation was voluntary, and no material compensations were offered in exchange for participation. Participants remained anonymous and were assigned survey numbers. To ensure understanding of the instrument items, all surveys were conducted face-to-face in Malagasy with an experienced translator-guide from the Maromizaha area. To address the possibility that respondents sometimes anticipate tangible benefits deriving from research participation, consent forms read to each respondent explained in Malagasy that they would receive no benefits other than knowing that they had contributed to the research project.

LIMITATIONS OF THE STUDY DESIGN. At the time the survey instrument was designed, our knowledge of the rice agriculture dynamics in the area were limited to what we gleaned from the literature and what we discussed with those who worked in the area. A false dichotomy between *tavy* and SRI was represented in the literature, but we found that some farmers had multiple fields (both upland and lowland) and used multiple rice agriculture techniques. The survey instrument yields insights about the techniques that SRI farmers and non-SRI farmers employed in their rice fields (e.g. spacing between seedlings, age at planting of seedlings, etc.). However, we cannot assess in detail other agricultural methods in the study area apart from SRI and *tavy*. The survey instrument is included in the supplementary materials. Results of only a small subset of questions are detailed in this paper.

RESULTS

SAMPLE OVERVIEW. A total of 174 household questionnaire surveys were completed in the villages surrounding Maromizaha Forest, with only 17 households of those asked declining to participate in the research. In total, surveys included approximately two-thirds (66%) of the 262 total households recorded by Surrans (2015). Although the number of households in the area has increased since 2015, we sampled all available households that were willing to participate, assembling a robust sample of farmer perspectives for the study. Respondents were engaged across the nine villages (Figure 2). Of the 174 respondents, 164 farmed rice and only 10 did not. Respondents were 52.3% male, 47.7% female and ranged in age from 18 to 80 with a median age of 40. Although many respondents identified with more than one ancestral group, the majority of respondents identified themselves as Betsimisaraka (68%), followed by Bezanozano (9.7%), Merina (8%), Betsileo (2.3%), Sihanaka (2.3%), Antaimoro (1.1%) and Antandroy (1.1%).

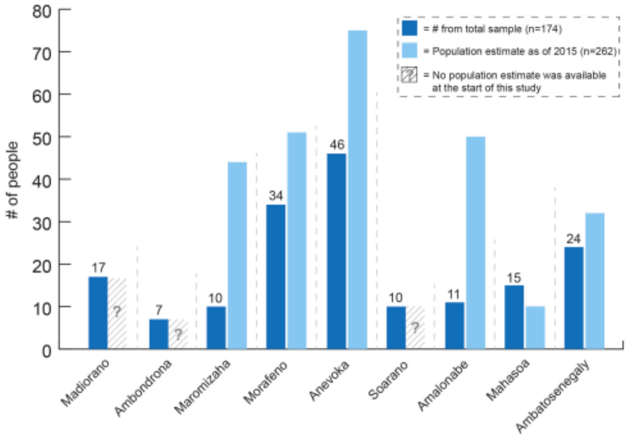


Figure 2. Sample size by village. (Sample size compared with total population estimates used in Surrans [2015]. Where bars are absent, population estimates were unavailable at the start time of the study)

SRI FAMILIARITY AND USE. The 164 rice-farming respondents were asked about their degree of familiarity and use of the SRI method. Just 12 (7.3%) reported that they employed SRI in their rice fields, all of them having participated in training on SRI techniques. A further seven respondents (4.3%) attempted SRI but subsequently disadopted it, four having received training. In addition, 14 respondents (8.5%) had heard of SRI and had trained in it but had never attempted it, and 75 respondents (45.7%) had heard of SRI but had no other experience with it. A total of 56 respondents (34.1%) had not heard of SRI at all at the time of the study. In summary, 65.9% of all respondents had heard of SRI, and 18.3% were formally trained in SRI methods; only 7.3% were using SRI at the time of the study (Figure 3).

Of the 12 respondents who were still practicing SRI, 7 respondents (58.3%) were from Anevoka, the central-most village where GERP and Peace Corps agricultural training efforts are centered. Outside of Anevoka, SRI was practiced by one respondent (8.3%) from each of the villages of Morafeno, Mahasoa, Maromizaha, Ambatosenegaly, and Madiorano (Figure 4), demonstrating a pattern of SRI adoption around Maromizaha Protected Area that varies by location and more specifically, by proximity to training resources.

PERCEPTIONS OF SRI YIELD. Ideally, we would hope to calculate gains from SRI use compared with other rice agriculture methods used around Maromizaha Protected Area, comparing es-

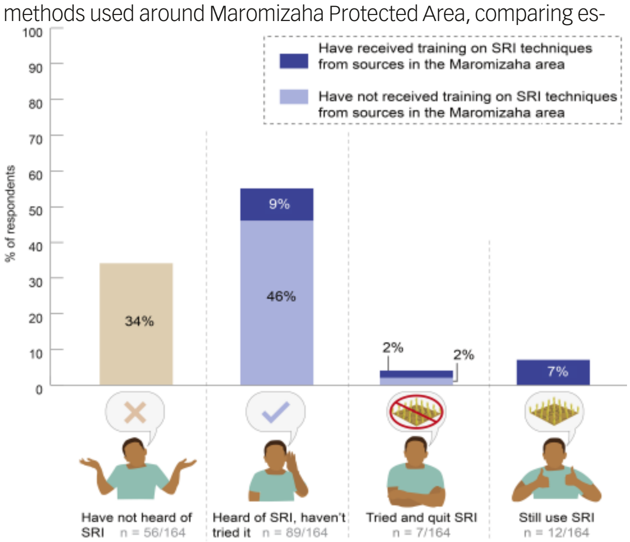


Figure 3. SRI knowledge and adoption. (Numbers are rounded to the nearest whole number for clarity)

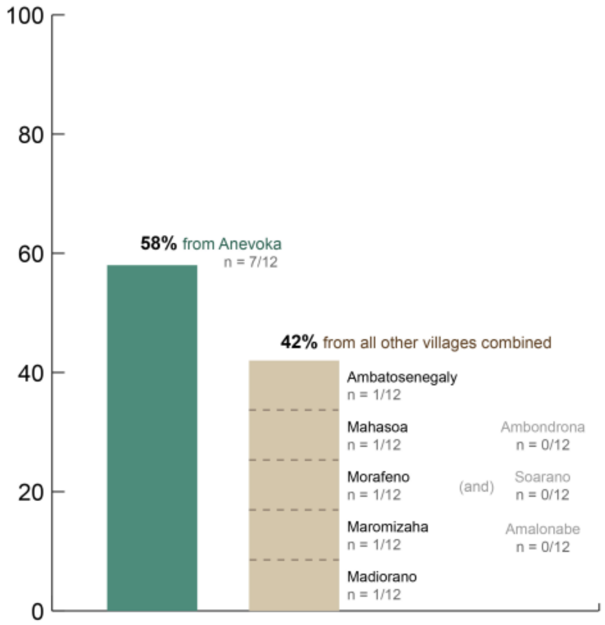


Figure 4. Village of residence: SRI respondents. (Numbers here are rounded to the nearest whole number for clarity)

timates of their yields together with the cost of inputs for each method. Few farmers were able to provide such estimates, so we instead evaluated farmers' perceptions about rice yields. SRI respondents were asked whether they would use SRI again next year, and whether they thought utilizing SRI techniques had increased their yield from what was obtained using a previous rice growing method. Notably, 100% of those who had ever attempted SRI, even those who quit, responded that they perceived an increase in yield with SRI. In addition, 100% of respondents who were using SRI at the time of the survey reported that they would use it again the following year. To reduce the chance that responses might be influenced by participant perception that researchers and NGOs view SRI positively, we made a clear effort to demonstrate a neutral research perspective in our informed consent process, noting that we were neither for nor against the use of SRI.

USE OF *TAVY*. As few farmers near Maromizaha were using SRI, we explored how many were using *tavy*. When asked about this, 139 of 164 (84.8%) respondents reported their current farming method to be *tavy*, with notable variations in the definition of the term *tavy*, and many farmers noting that they used multiple plots with different rice agriculture methods on each plot. Many people use the term "*tavy*" to refer to any hillside rice, regardless of use of fire. Importantly, 41.7% of farmers who use SRI also utilize *tavy* in other plots.

FACTORS THAT INFLUENCE SRI ADOPTION. With regard to the relationship between SRI adoption and labor resources, the median number of family members who help with farming was 2.5 among the 12 respondents who continue to practice SRI, compared with a lower median of just two helpers for the entire study sample (Figure 5).

Finally, to inform future studies, we noted any reasons that farmers expressed about deciding to disadopt SRI. One respondent reported that he disadopted SRI after the training program ended, a second quit because it was too difficult to do both SRI and *tavy*, a third quit because he perceived an increase in crop vulnerability to

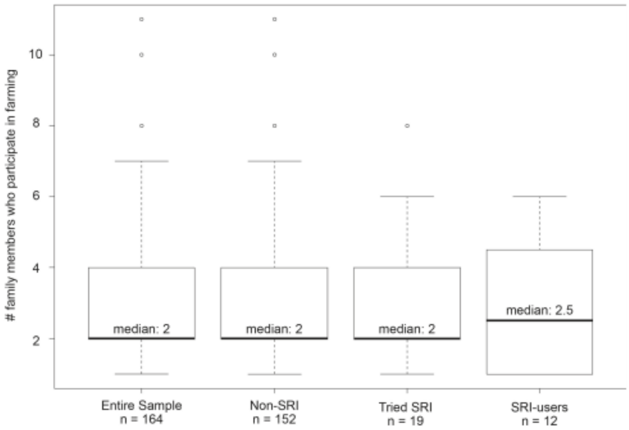


Figure 5. Number of family members who help with farming.

rats in SRI fields, and a fourth did not specify a reason for disadoption. The three remaining respondents reported having utilized SRI in their former residences (Antananarivo, Antsirabe and Beforona) commenting that they were unable to continue it upon relocating to the Maromizaha area, suggesting issues with suitable land availability. Although anecdotal, discontinued use of SRI among these farmers can provide insights into the challenges facing future implementation efforts of SRI around Maromizaha and elsewhere.

DISCUSSION

This study revealed that although most rice farmers around Maromizaha have heard of SRI, few have tried and continued practicing it. This is interesting in light of the reported positive perception of the method's ability to increase rice yields. Relatively few farmers have been trained in SRI techniques, and the fact that most SRI-users are from the village where training organizations are based suggests that broadened access to education and training may increase implementation of the method, particularly in isolated areas.

The compound aim of SRI is to increase rice yields, dissuading farmers from clearing upland slopes for *tavy* farming and indirectly decreasing deforestation pressure, which rests on several assumptions (Byerlee et al. 2014). All of the rice farmers who practiced SRI in the area perceived yields with SRI to be higher and would use the method again. However, a majority of farmers in the Maromizaha area reported use of *tavy*. Indeed, most farmers practicing SRI in some of their fields also continue to practice *tavy* in other fields. Efforts to introduce sustainable agricultural practices must further assess and take into account the reasons why *tavy* is still so widely used by Malagasy smallholder farmers. For example, SRI requires a different type of rice than is grown using *tavy*, and many farmers anecdotally report that the rice grown using *tavy* tastes better and is more filling. Future research exploring farmer preferences towards *tavy* and different varieties of rice will be important.

Of course, adoption of SRI may be easier in cases where more labor resources are available to contribute to farming efforts (Moser and Barrett 2003, Brimont et al. 2015). Informal observations suggest that those who currently have the ability to practice lowland, irrigated rice agriculture already have access to more labor resources, increasing their ability to adopt a method like SRI. Indeed, some farmers mentioned that they would be willing to try SRI if they had more help with the labor. Future studies might explore feasibility of farmer cooperatives to share both labor and harvests, facilitating labor-intensive SRI techniques at scale.

In a hilly area such as Maromizaha, many *tavy* farmers do not have the type of land necessary for SRI, and would first have to clear an adequate lowland field for farming. A significant amount of lowland area would need to be converted to fields in order for most people in Maromizaha to practice SRI. To this end, it may be useful to use existing GIS and satellite image data to create a feasibility map for lowland rice farm construction around Maromizaha, together with an environmental impact assessment. Development initiatives in many regions in Madagascar have provided support for the construction of small-scale dams that aid in the irrigation of lowland fields, a task that can be difficult for farmers. One such dam exists near Maromizaha (Brimont 2015). However, such a project on a large scale would be expensive, with other complications in terms of sustainability and equitable distribution of benefits. Given these considerations, it may prove more practical to target SRI training efforts and labor support at farmers already using lowland rice fields who may be more prepared to adopt and succeed with SRI. For farmers who are not equipped to practice SRI, however, targeted support for other rice agriculture methods could be useful.

In 2003, Moser and Barrett published a five-village study on the adoption of SRI, noting high rates of disadoption and a critical mismatch that demands SRI labor at a time when liquidity is low and labor effort is already high (Moser and Barrett 2003). Several studies have questioned the efficacy of SRI as a farming strategy in upland settings, and the sustainability of intensification more generally at large scales (Dobermann 2004, Sheehy et al. 2004, Perfecto and Vandermeer 2010, Byerlee et al. 2014, Brimont et al. 2015, Gossner et al. 2016). Brimont et al. (2015) examined complexities of poverty and climate vulnerability in northeastern Madagascar, noting that lowland fields are more prone to cyclone damage, and that those with minimal resources tend to rely on upland *tavy* as a risk management strategy. Given these findings, together with the low adoption rates of SRI in Maromizaha found here, the fact that SRI is still being promoted broadly without better understanding of how it performs in relation to elevation, soil characteristics, or farmer resources is concerning. We encourage that best practices be developed in consultation with stakeholders with farming experience *in situ*. It is clear that improvements in food security and conservation outcomes require improved communication, improved accessibility to information at all levels to various stakeholders in all relevant languages, with a reaffirmed dedication to consulting empirical evidence (e.g., the PRISM toolkit available through the Conservation Evidence project by Petrovan et al. 2018).

Lastly, it is not uncommon to hear the opinion that farmers who do not use SRI are 'lazy' and unwilling to adopt new techniques, or that low adoption is to be expected in behavior change initiatives. To quote Moser and Barrett (2003), "failure to take disadoption seriously signals an implicit assumption that new technologies are unambiguously superior to older ones" ignoring past and present local agricultural knowledge. Moving forward, conservation and development efforts can improve through better consulting and representing marginalized groups such as resource-poor smallholder farmers.

CONCLUSIONS

Madagascar has received targeted biodiversity conservation attention for decades. As pointed out by Pollini (2010), conservation efforts have largely failed in decreasing deforestation rates and have at times occurred at the cost of local livelihoods, creating a critical gap between the realities that Malagasy farmers experience and the representation of those realities by conservation and development actors. This gap is still apparent today in what Sutherland and Wordley (2017) would call a culture of "evidence complacency" that pervades many areas of science and policy, including present discussions of SRI promotion. Rice remains of critical importance to the culture and food security of communities living near Maromizaha Forest, hence agricultural solutions that improve soil quality and crop yields while minimizing land degradation are imperative. This paper offers a deeper understanding of the dynamics of agricultural decisions made in proximity to Maromizaha Protected Area. We encourage enhanced dialogue among local community members and protected area management organizations to help inform decision-making strategies, with the goal of improved sustainable food security and biodiversity conservation outcomes across a complex assemblage of stakeholders.

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SUPPLEMENTARY MATERIAL

S1. Survey instrument used in this study.

S2. Étude d’Impact et Environnemental de Maromizaha. 2015. GERP, Antananarivo.

S3. Plan d’Aménagement et de Gestion (PAg) de la Nouvelle Aire Protégée de Maromizaha. 2015. _GERP, Antananarivo.

S4. Élaboration du Plan d'Aménagement et de Gestion (PAG) de la Nouvelle Aire Protégée de la Forêt Humide de Maromizaha. Période 2015–2019. 2015. GERP, Antananarivo.

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