CARDON RESEARCH PAPERS
IN AGRICULTURAL AND RESOURCE ECONOMICS

Research Paper Number 202002

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The methods used to cultivate rice are evolving as researchers innovate and develop agronomic practices to increase yield and farmer income. In the previous two decades, members of the RICE CRP, including IRRI, CIAT, and AfricaRice created and disseminated regionally-designed and locally-appropriate portfolios of agronomic practices in collaboration with local partners. These agronomic practices include 3 Reductions, 3 Gains (3R3G) and 1 Must Do, 5 Reductions (1M5R) in Vietnam; 10 and 10+ Practices in Brazil; and Smart-Valley or Sawah in West Africa. This paper presents the current available evidence on the diffusion and adoption of these technologies. While much has been written about these technologies, we find that previously published levels of dissemination and adoption tend to be inflated. However, this does not mean that the adoption of these technologies is limited. We document reliable sources of data on adoption for each technology and, where appropriate, use these data to estimate adoption rates in the regions of interest.

Dissemination and Adoption of Bundled Agronomic Practices*

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February 2020

Abstract

The methods used to cultivate rice are evolving as researchers innovate and develop agronomic practices to increase yield and farmer income. In the previous two decades, members of the RICE CRP, including IRRI, CIAT, and AfricaRice created and disseminated regionally-designed and locally-appropriate portfolios of agronomic practices in collaboration with local partners. These agronomic practices include 3 Reductions, 3 Gains (3R3G) and 1 Must Do, 5 Reductions (1M5R) in Vietnam; 10 and 10+ Practices in Brazil; and Smart-Valley or Sawah in West Africa. This paper presents the current available evidence on the diffusion and adoption of these technologies. While much has been written about these technologies, we find that previously published levels of dissemination and adoption tend to be inflated. However, this does not mean that the adoption of these technologies is limited. We document reliable sources of data on adoption for each technology and, where appropriate, use these data to estimate adoption rates in the regions of interest.

JEL codes: O13, Q12

Keywords: technology adoption, agronomic practice portfolios, 3R3G, 1M5R, Project 10/10+, Smart-Valley

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Thanks to Aminou Arouna, Robert Andrade, Ricardo Labarta, Hung Van Nguyen, and Valerian Pede.

1. Introduction

Rice is the most important food crop in the world, feeding more than half of the world's population (FAO, 2008). Certain techniques for growing rice have been commonplace since the crop's domestication, including puddling of soil and transplanting of seedlings. However, methods continue to evolve: researchers innovate and develop agronomic practices to increase yields and farmer income. Members of the RICE CRP, including International Rice Research Institute (IRRI), the International Center for Tropical Agriculture (CIAT), and AfricaRice have created and disseminated regionally-designed and locally-appropriate portfolios of agronomic practices in collaboration with local partners, including 3 Reductions, 3 Gains (3R3G) and 1 Must Do, 5 Reductions (1M5R) in Vietnam; 10 and 10+ Practices in Brazil; and Smart-Valley or Sawah in West Africa. This paper presents the current available evidence on the diffusion and adoption of these technologies.

While much has been written about these technologies, we find that reliable data on dissemination and adoption is often lacking. Some of this is due to the age of these agronomic practices. Standards of academic rigor have changed in the two or more decades since these technologies were first introduced. What sufficed for evidence of adoption in 2002 is no longer sufficient in 2020. Based on our critical reading of the literature and our own data collection efforts, we find that previously published levels of dissemination and adoption for all of the technologies under consideration are inflated. That is not to say that adoption of several of these technologies is limited. Based on monitoring data from four of the 13 provinces in the Mekong River Delta in Vietnam, we find nearly 70,000 hectares qualify as fully adopting 3R3G or 1M5R (eight percent of total rice area). Using project monitoring data from the state of Rio Grande do Sul in Brazil, we find total land area under Project 10 or 10+ to be over 60,000 hectares (six percent of total rice area). Across Nigeria, Ghana, Benin, and Togo, we are able to confirm that Smart-Valley or Sawah has been adopted on about 3,000 hectares (0.04 percent of potential inland valleys).

In all cases, these numbers represent a lower bound, based on data we could verify or corroborate. They represent the number of confirmed full adopters, or confirmed hectares under adoption, as a share of total farmers or land area in the region. In many cases, these confirmed adoption numbers come from representative samples, so one could extrapolate from them to estimate much higher, though still reasonable, adoption rates. We refrain from presenting these estimated adoption rates until the conclusion.

In the following sections we review each technology, beginning with a description of the technology, followed by a presentation of the results on dissemination and adoption. We begin with 3R3G and 1M5R in Vietnam, followed by Sawah/Smart Valley in West Africa, and conclude with Project 10/10+ in Brazil. We briefly conclude, summarize the findings from across the literature, presenting limitations and next steps for research on bundled agronomic practices.

2. 3R3G and 1M5R in the Mekong River Delta, Vietnam

2.1. Description of the technology

To address the inefficient use of inputs by rice farmers in Vietnam, two portfolios of management practices have been developed and disseminated. The practices were disseminated across the country, but efforts were concentrated in the Mekong River Delta (MKD). Historically, rice farmers in the MKD overused inputs, particularly seed and fertilizer. This generated ideal breeding conditions for pests, which also drove the overuse of pesticide (Huan, 2005; Stuart, 2018). Both fertilizer and pesticide, when overused, can leach into water supplies and have detrimental effects on human and environmental health.

Two programs were developed at different points in time to mitigate these concerns. The first, "3 Reductions, 3 Gains" (3R3G), was disseminated to farmers in 2003. 3R3G built on IRRI's earlier work in developing a system of integrated pest management (IPM) to reduce pests without increasing pesticide use. IRRI expanded the IPM system to include reduced seed rates and reduced fertilizer application rates. 3R3G specifically advocates for reducing seed rates to 100 kg per hectare, reducing fertilizer application rates to 130 kg of nitrogen per hectare, and reducing pesticide application to no more than four times per year. The rational is that by reducing seed rates, farmers can reduce the existence of pest-breeding microclimates that form below the dense canopy of closely sewn plants. With the reduced number of plants per hectare, farmers no longer need to apply as much fertilizer, thereby reducing the amount of nutrients pests can feed upon. Overall, the result is a reduced need for pesticides, as the first two reductions help eliminate environments favorable to the breeding of pests. Ultimately, all three reductions lead to higher yields (through few pest infestations), better quality rice (through less chemical residue), and higher profits (through lower production costs).

Around 2009, the second program "1 Must Do, Five Reductions" (1M5R) was introduced, to expand on 3R3G. Under 1M5R, the objectives were the same: to have higher yields, better quality rice, and higher profits, with improvements in human and environmental health. However, the particulars of the program changed: one practice was set apart as a "must do" and there were five reductions, instead of three. The "1 must do" represents the use of certified seed. The five reductions, include the three from 3R3G: (1) fertilizer, (2) pesticide, and (3) seeding rates, as well as two additional reductions. Farmers were now encouraged to (4) reduce water use, through the application of alternate wetting and drying (AWD), and to (5) reduce post-harvest loss, through the use of combine harvesters.[1]

[1] Combine harvesters are widely available in Vietnam (Takeshima et al., 2018).

2.2. Evidence of dissemination and adoption

3R3G was widely disseminated throughout the MKD, with support and endorsement from the Department of Agriculture and Rural Development (DARD). In 2006, the program was made a national priority; 3R3G was disseminated through mass media advertising and farmer training (Huan et al., 2008). International lending agencies, research consortiums, and provincial governments have also promoted 3R3G. Heong et al. (2010) indicate that by 2008 more than two million farmers had been reached by the mass media information campaigns disseminating 3R3G, though the authors provide no information on how they arrived at that number. Further, "reached" does not indicate practice or adoption of the agronomic practice.

In addition to dissemination campaigns, DARD administered six-day trainings and built demonstration test plots, to show the effectiveness of 3R3G and later 1M5R. The standard training package for each technology is a six-day series, although farmers could also be "re-trained" on 1M5R, if they were trained on 3R3G, in a shorter three-day series. Farmers respond strongly to the trainings. In author-conducted field group discussions in September of 2019, farmers reported interest in the program following the trainings and belief in the potential of the practices after observing field trials. Farmers indicated that because of the field trials and demonstration plots, they were sound in their understanding of the program's practices and potential effectiveness.

Because of the extensive promotion campaigns and trainings, many farmers in the MKD are familiar with 3R3G and 1M5R. The success of the campaigns has been heralded in the literature as a resounding success (Huelgas et al., 2008; Heong et al., 2010; Singleton et al., 2011). As an example, Huan (2008) claim that farmers in two provinces of the MKD were asked if they *knew about* 3R3G. In Can Tho and Tien Giang provinces 82 and 56 percent of farmers, respectively, knew about the technology.

Further evidence has relied on provincially reported data to estimate the number of farmer trainings conducted, the number of farmers who have been trained who are applying 3R3G or 1M5R methods, and the associated number of hectares. According to Heong et al. (2010), as of 2008, just under 400,000 hectares in the An Giang province of the MKD were under 3R3G practices (Figure 1). This represents an adoption rate of over 85 percent of total rice area in the province. On a visit by the authors to the DARD office in Long Xuyen in September 2019 we were unable to confirm these numbers, however. In fact, DARD officials provided lower, and much more reasonable, adoption numbers.

Taken as a whole, the adoption numbers published in academic journals during the 2005 to 2015 period present the efforts of the Vietnamese Government to promote 3R3G and 1M5R as an astounding success. Papers frequently cite adoption rates of well over 50 percent of farmers or hectares with some reporting nearly universal adoption. Based on our own data collection efforts we are unable to substantiate any of these early claims to near universal adoption. Additionally, in interviews DARD officials reported adoption numbers well below these early figures published in the academic press.

We believe the primary reason for the downward revision of adoption numbers has been a set of rigorous data collection efforts introduced by DARD in collaboration with IRRI and Vietnam Sustainable Agriculture Transformation Project (VnSAT). Table 2, which presents data from Singleton and Nguyen (2017), shows the number of trained farmers and the hectares cultivated by these farmers are much lower than either Singleton et al. (2011) or Heong et al. (2010) reported. Starting with the funding of VnSAT by the World Bank in 2015, DARD and the Government of Vietnam have taken a more systematic approach to monitoring the dissemination and adoption of 3R3G and 1M5R. Each district DARD office is now required to collect a complete list of farmers from every farmer organization in their region. These lists are forwarded to the Central Project Management Unit (CPMU), which randomly selects five percent of names from the list. The district DARD office then surveys these randomly selected farmers so as to measure if they were trained, if they are using (in Vietnam, referred to as "applying") either 3R3G or 1M5R, and if they qualify as having fully adopted either of the technology. The lists are updated twice a year so that data is collected on a new randomly selected set of farmers during the two major rice growing seasons.

A second reason for the downward revision of adoption numbers is that VnSAT has now defined clear criteria for adoption. Further, farmers are required to keep detailed diaries throughout the season in order to demonstrate that they have in fact adopted. This has given rise to a distinction between farmers: (1) *qualified adopters*, who have qualified as full adopters and (2) *applying adopters*, who are using the portfolio practices, but not completely. VnSAT considers a farmer to have qualified as an adopter if they have met or exceeded all of the criteria as defined in Table 1. In order for a farmer to demonstrate that they have qualified, the farmer must produce their farm diary in which they have recorded their input use and farm practices. The incentive to qualify is that if a sufficient number of farmers in a commune reach qualified status then VnSAT will allocate infrastructure funds to that region.[2] Farmers, and hectares, which are applying 3R3G or 1M5R but do not yet meet the prescribed standards and considered to be "applying" the technology, though they have yet to qualify. In interviews with DARD officials and local farmers, meeting the reduced seed rate target and applying AWD are the major constraints that keep applying farmers from becoming qualified farmers. This conclusion is confirmed in IRRI's 2018 progress report (Singleton,

[2] This, of course, may provide an incentive to overreport adoption.

2019).

VnSAT's systematic approach to documenting adoption has resulted in lower, more reasonable, but still impressive adoption numbers. As an example, Huelgas et al. (2008) report that adoption of 3R3G in An Giang and Can Tho provinces in 2006 was 80 percent. Yet the authors define adoption "as farmers who have stated that they heard about and believed in the principles of 3R3G and have, to some degree at least, taken up one or more of the 3R3G recommendations" (Huelgas et al., 2008, p. 5). With such a lax definition of "adoption" it is no wonder that early literature presented nearly universal adoption numbers. Table 3 presents adoption numbers for four of the thirteen provinces in the MKD based on our own interviews with officials and from administrative data. As of 2019, approximately 44,000 farmers are qualified on 3R3G (fully adopted) covering 70,000 hectares while 35,000 farmers are qualified on 1M5R covering 55,000 hectares. This represents between 30 and 50 percent of all rice farmers in these four provinces. While admittedly lower than the near universal adoption reported in the academic press a decade ago, we believe these numbers are more reasonable while still representing wide-spread adoption of the technologies.

3. Smart-Valleys or Sawah in West Africa

3.1. Description of the technology

Historically, rice production in West Africa has been limited of insufficient water to meet the crop's water requirements. Sawah or Smart-Valley is a set of practices that adapt natural rainfall basins (inland valleys) through relatively low-cost infrastructure to control seasonal rains for rice production (Zwart, 2014; Rodenburg, 2013). Sawahs are rice fields that have been leveled, puddled (small depressions made around the rice plants), and bunded (retaining walls). Canals are also part of Sawah as they redirect water from dams, rivers, or reservoirs to fields. Sawah encourages the use of nurseries to develop seedlings instead of scattering seed into the field. Nurseries improve the rate of germination and each rice crop, once transplanted to the field, can be evenly spaced to reduce overcrowding. Sawah has been introduced to inland valleys in Togo, Benin, Nigeria, and Ghana because of a prevalence of rainfed agriculture in those countries.

3.2. Evidence of dissemination and adoption

Sawah was first introduced to West Africa in 1986 on two research sites in the Gara and Gadza valleys of Nigeria. Since then, there has been little systematic study of dissemination or adoption of the technology in the rice-growing states of Nigeria. What little research exists has primarily focused on understanding the behavior of households that have already adopted Sawah, not measuring the extent of adoption. Alarima et al. (2018) provides a recent example: the authors surveyed 300 farmers who had already adopted Sawah Kebbi State and found that 100 percent of respondents adopted bund construction, 99 percent adopted nurseries, 98 percent adopted puddling, and 94 percent had leveled their fields. While this tells us about the characteristics of adoption for adopting farmers, it tells us nothing about traits of those adopters or the outcomes of adoption.

A recent unpublished study of Sawah in Nigeria has attempted to remedy the lack of data relevant to adoption estimates. Wakatsuki et al. (2018) use Google Earth images to visually identify areas in Kebbi state using Sawah. They find that 20 percent (2,000 hectares) of the Rima River flood plan appears to be adopting Sawah in 2016. The authors then extrapolate from that 10 percent figure to claim that 45,000 hectares (10 percent of flood prone areas) in Kebbi have adopted Sawah. The authors fail to explain if their visual identification of Sawah use was based only on bunds or if they were also able to use the images to determine if the land was leveled and puddling was used.

Subsequent to its introduction to Nigeria, on-station trials of Sawah were conducted in Ghana in 2006 and 2009. The technology slowly diffused. Ragasa et al. (2013) find that 15 percent of the rice growing area in their sample of 576 farmers used the Sawah technology. Unlike other studies in Nigeria, Ragasa et al. (2013) developed a three-stage random sampling strategy to ensure their sample was representative of irrigated rice production in Ghana. Overall, the authors found that 37 percent of farmers practice bunding, 33 percent leveled their fields, and only 15 percent practiced puddling. The authors conclude that puddling is the limiting factor to more widespread adoption of Sawah in Ghana.

In addition to Ghana and Nigeria, Sawah has been disseminated in Togo and Benin. The Japanese government and AfricaRice began the Smart Inland Valley (Smart-IV) project to introduce Sawah to Togo and Benin in the 2010s. The aim of Smart-IV was to "explore the potential of the Sawah system for increasing rice productivity in inland valleys, while improving farmer access to markets and rice technologies" (AfricaRice, 2015). Smart-IV organized nine Sawah trainings, which included training 87 technicians in Sawah, as well as 47 lead farmers. Further, in six agricultural zones in the two nations, a total of 28 demonstrations sites were developed. At the project's conclusion in 2014, Sawah had been adopted and operationalized on 139 sites in the two countries. This represented a total area of 340 hectares: 205 hectares in Benin and 135 hectares in Togo (Figure 2 and Figure 3). In a two-country survey conducted in 2014-15, AfricaRice found that 56 percent of farmers that were trained in Sawah adopted Sawah as a rice production technique. The survey was designed to allow for the measurement of impacts from adoption by selecting control households from villages that were similar in population, rice growing ecology, geographic proximity, and general agricultural practices. However, because "adopting" and "non-adopting" households were selected in similar proportions, this data is ill-suited to estimating adoption rates more generally in Benin and Togo.

The best data on adoption of Sawah in Benin and Togo comes from Arouna and Akpa (2019). They find that in 2012 Sawah had been adopted on 233 hectares: 101 hectares in Benin and 132 hectares in Togo. The authors indicate that adoption rose to as much as 474 hectares in Benin by 2014. However, the two estimates are based on two different methods of evaluation. The first, smaller figure is calculated using satellite images of identified fields, though the authors do not explain how they use satellite imaging to estimate the practice of Sawah. The second, larger figure is based on farmer survey responses, from a sample of 590 randomly selected rice farming households. The authors also do not report a new 2014 adoption rate for Togo.

Using the survey data, the authors calculate adoption statistics for farmers in Benin and Togo (Figure 4). They find that in 2014, 50 percent of respondents knew of Sawah and 29 percent of respondents used Sawah. In 2015, 34 percent of respondents knew of Sawah and 18 percent used Sawah. While the authors report these figures, important information on the data sampling or collection procedure is missing in the paper. As such, we do not have insight as to why fewer respondents knew about Sawah in 2015 than in 2014, even though no new respondents were added in 2015.

4. Project 10 and Project 10+ in Brazil

4.1. Description of the technology

Project 10 was initiated by the Latin American Fund for Irrigated Rice (FLAR), CIAT and the Rio Grandense Rice Institute (IRGA) to increase rice production for rice farmers across the South Rio Grande. Project 10 emphasized a variety of different agronomic practices including: sowing date, plant nutritional status, soil fertilization, management of irrigation water and weed control, soil adequacy practice, cultivar selection, and insect and disease management. Details on the portfolio are presented in Table 4.

To promote Project 10, extension specialists were trained to educate rice farmers, technicians, and other field workers. Trainings occurred as an iterative process in which groups would follow the recommendations of Project 10 and then share their experiences with others in and/or outside the group. In this way, Project 10 was intended to be a producer-to-producer disseminated technology, in which training groups would interact, teach one another, and eventually teach other outside the group. Within the training, the group would follow a set of “moments”, across the crop season, including before planting, after seedling emergence, at the end of the flowering process, and during the harvest season. In each moment, groups would discuss the current standard methods and requirements of Project 10. Groups met throughout the growing season, where field days and showcases were carried out at different Rice Experimental Stations or farmers' fields. According to IRGA (2013), from 2003 to 2011, approximately about 17,000 individuals were trained.

From 2011 to 2016 rice production in the Rio Grande do Sul became stagnant despite advances in technology and promotion of Project 10. This led to FLAR, CIAT, and IRGA, to create Project 10+. Like its predecessor, this program followed the producer-to-producer concept. However, Project 10+ was paired with a specific goal: to increase the average yield of rice in the region to 8.50 tons/ha within the next three years and to reach 100 municipalities (for a total of 2,000 producers practicing Project 10+), by the 2016-17 harvest season (IRGA, 2016).

While Project 10 focused on distributing technology and methods, Project 10+ simplified these methods so that they were easy to use by farmers with different technology and systems. The specifics of Project 10+ are presented in Table 5. The features of Project 10+ are designed to build on one other so that they are the most effective if they are completed together and in a logical, recommended order. Project 10+ uses herbicides and improved seed varieties that are resistant to those herbicides so that weeds cannot compete with the rice crops but the rice crops are not damaged by the herbicides used to kill the weeds. The improved rice seedlings should be optimally spaced, at a rate of 150 to 200 rice plants per square meter. This keeps plants from over competing but utilizes as much space as efficiently as possible. Fertilizers should be applied to field at a rate of six tons per hectare. This amount is greater than the average amount of fertilizer used by Brazilian rice growers but follows directly from the sowing recommendations. Water must be used efficiently and so to use water optimally rice fields should be flooded when the rice plants have three to four expanded leaves. After flooding, water should remain on the field at a depth of five to ten cm. This differs from past practice which recommended a level of 15 cm.

4.2. Evidence of dissemination and adoption

Project 10 and 10+ are designed to be diffused through producer-to-producer interactions. Generally, lead farmers serve as primary disseminators of the knowledge. In the region, farmers have a tradition of cultivate test plots, experimenting with new methods or technologies. These test plots play an important role in the diffusion of Project 10 and 10+ technologies as they allowed farmers to learn and observe the technologies in practice. Test plots, and field days to showcase the technologies, are ongoing so farmers can observe the technologies at their convenience (Andrade & Labarta, 2019). Table 7 reports the number of producers cultivating test plots, as well as the corresponding area and yield for 2016-2017 and 2017-2018 seasons. When Project 10 was officially implemented in the 2003-2004 growing season, farmers in the region cultivated 294 test fields covering 9,248 hectares. Over the next decade Project 10 expanded; in 2011 447 project fields covering 65,111 hectares were established across six different regions (IRGA, 2013). Project

10+ had a similar diffusion process, growing out of demonstrative test plots. Diffusion for Project 10+ began with 60 demonstration units, later expanding to 94 demonstration units, and 800 producers, located in 22 municipalities (IRGA, 2016).

In addition to test plots, in order to encourage famers to adopt, IRGA held trainings and farmer workshops to inform farmers about the technologies and practices of Project 10 and 10+. Table 6 presents the trainings which were completed by IRGA within the first eight years of the Project 10 program (IRGA, 2013). IRGA reports that trainings helped farmers learn about technologies and implement them effectively. Further, within the first year of the Project 10+ implementation 25 percent of farmers were able to perform all the procedures that were recommended. However, for the other 75 percent of farmers, challenges made adoption of the full package of technologies not possible (IRGA, 2017).

IRGA indicates that adoption is widespread due to observed yield gains (IRGA, 2016). For example, region saw the most improvement given its past productivity levels: in the 1999-2000 season, only four percent of the area was producing more than seven tons per hectare. In the 2010-11 season, however, 84 percent of the area was producing more than seven tons per hectare. IRGA infers that this progress was due to the recommendations given by Project 10, though it is not possible to identify causality. CIAT also reports recent expansion of Projects 10 and 10+. Andrade and Labarta (2019) report that in 2015 there were 14 farmers practicing these methods on 4,801 hectares. By 2018, the area using these practices had expanded 150 percent and the number of farmers 227 percent to 61,886 hectares and 136 farmers.

IRGA conducted a famer census in Rio Grande do Sul in 2004-2005, and collects yearly monitoring datasets, which includes information on farmer production practices. Recent work from unpublished work from CIAT (Andrade, 2019) compares the non-randomly selected yearly monitoring data with the farmer census to understand adoption differences across the two populations. This work, presented in Figure 5 demonstrates the differences in these groups based on six elements of Project 10 / 10+, (1) sowing period, (2) soil tillage practices, (3) seed type, (4) seed density, (5) crop rotation, and (6) fertilizer practices. Based on these comparisons, the groups are generally similar, though slight differences exist. In particular, there are significant differences on seed density, fertilizer practices, and crop rotation. Generally, this suggests that the monitoring group is closer to the recommendations of Projects 10/10+, which follows expectation due to the non-random selection of the monitoring group. However, these groups are quite similar, suggesting that with respect to several of the practices of Project 10/10+, producer-to-producer diffusion and adoption have successfully occurred.

5. Discussion and Conclusion

Population growth and climate change continue to put demands on rice production systems. Globally, the agricultural sector needs to produce more food with fewer inputs. To help meet this need, local partners, IRRI, AfricaRice, and CIAT have been instrumental in developing regionally-designed and locally-appropriate portfolios of agronomic practices to help ensure a sustainable food supply.

We critically examine the evidence of adoption for 3 Reductions, 3 Gains (3R3G) and 1 Must Do, 5 Reductions (1M5R), Smart-Valley or Sawah, and 10 and 10+ Practices. Each of these technologies was developed and disseminated over 15 year ago and each has been adopted to varying degrees in Vietnam, West Africa, and Brazil, respectively. While the literature on these technologies has typically reported widespread adoption, we find many of these claims to be inaccurate. Studies frequently present adoption numbers without explaining where the underlying data comes from or how the numbers were calculated. Because of this, we take a very conservative approach and report only on dissemination and adoption numbers that we can confirm or corroborate. We find that in the Mekong River Delta nearly 70,000 hectares qualify as fully adopting 3R3G or 1M5R, which amounts to about eight percent of total rice area of that region. We find a similar rate of adoption in Rio Grande del Sol in Brazil, where 60,000 hectares use Project 10 or 10+, an adoption rate of six percent of total rice area in the region. In West Africa, we are only able to confirm adoption of Smart-Valley or Sawah on 3,000 hectares across Nigeria, Ghana, Benin, and Togo, which amounts to only 0.04 percent of potential inland valleys.

These adoption numbers are a lower bound as they represent confirmed full adopters, or confirmed hectares under adoption, as a share of total farmers or land area in the region. In many cases, these confirmed adoption numbers come from representative samples, allowing use to extrapolate from them to estimate adoption rates for the population more broadly.

- In the case of Vietnam, VnSAT's monitoring data is collected via random sampling from a census of rice growing households. Using the adoption rates within this random sample, we can estimate adoption rates within the four provinces we have data for (though not the other nine provinces for which we lack data). In the random sample, 30 percent of households fully qualify as adopting 3R3G and 1M5R. The total rice growing area in the four is 880,000 hectares. Average farm size in the provinces is 1.5 hectares, meaning there are approximately 590,000 farmers in Can Tho, Kiên Giang, An Giang, and Dong Thap. Thus, it is reasonable to estimate that 176,000 farmers are using 3R3G or 1M5R to cultivate 264,000 hectares. Again, it is essential to note that these adoption numbers only cover four of the 13 provinces in the MKD, as we cannot assume that adoption rates are uniform across all provinces.
- In the case of West Africa, the only adoption that that is representative comes from Ghana. Among the randomly selected households, 15 percent had fully adopted Sawah. In the country as a whole, irrigated rice production covers 6,729 hectares. Thus, a reasonable estimate is that there are 1,010

hectares under Sawah in Ghana. As data from Nigeria, Benin, and Togo is not representative, we cannot estimate the extent of adoption in these countries.

- In the case of Brazil, IRGA has non-random sampled monitoring data which can be compared with the randomly sampled Census. Comparing these samples, we can estimate adoption rates for the Rio Grande do Sul region more broadly. Within the monitoring survey, approximately 25 percent of farmers fully adopt Project 10/10+ practices, equivalent to about 775 farmers in the monitoring data or 116,000 hectares. Applying this rate of adoption to the 9,000 farmers interviewed in the Census suggests adoption by about 2,250 farmers or 338,000 hectares (about six percent of the total rice growing area in Rio Grande do Sul).

These calculations suggest relatively broad adoption in the regions where the technologies were diffused, albeit not as large as some other, previously published adoption figures.

While we are unable to confirm that adoption rates of these portfolios of practice are as high as the figures from some earlier published reports, there is strong evidence of widespread adoption for several of the technologies. Yet, even where adoption data is rigorous and reliable, it frequently only records households as either full adopters or complete non-adopters. This leaves scope for future research to more thoroughly document cases of non-binary adoption as well as estimate the impact of wide-spread, long-term adoption of these bundled agronomic practices.

References

Alarima, C.I., Awotunde, J.M., Adamu, C.O., Akerele, D., Masunaga, T., and Wakatsuki, T. 2018. Adoption of sawah eco-technology in rice production by farm households in Kebbi State, Nigeria. *Journal of Water and Land Development 37*: 11-7.

Andrade, R. 2019. Comparative Analysis of IRGA Monitoring and IRGA Farmer Census Data. Shared via personal communication.

Andrade, R., Labarta, R. 2019. Impact Assessment of Rice Agronomic Practices in Southern Brazil. CIAT – Applied Economics Lab Presentation RICE CRP Flagship 1: Rome, Italy, 23 May 2019.

Arouna, A., Akpa, A.K.A. 2019. Water management technology for adaptation to cimate change in rice production: Evidence of Smart-Valley approach in West Africa. In *Sustainable Solutions for Food Security: Combating Climate Change by Adaptation*. Sarkar, A., Sensharma, S.R., and vanLoon, G.W. (eds.). Geneva: Springer Nature.

Food and Agriculture Organization (FAO). 2008. *FAO and Sustainable Intensification of Rice Production for Food Security*. Rome: FAO.

Heong, K.L., Escalada, M.M., Huan, N.H., Chien, H.V., Quynh, P.V. 2010. Scaling out communications to rural farmers: lessons from the "Three Reductions, Three Gains" campaign in Vietnam. In *Research to Impact: Case Studies in Natural Resource Management for Irrigated Rice in Asia*. Palis, F.G., Singleton, G.R., Casimero, M.C., and Hardy, B. (eds.). Los Baños: IRRI.

Huan, N.H., Chien, H.V., Quynh, P.V., Tan, P.S., Du, P.V., Escalada, M.M. and Heong, K.L. 2008. Motivating rice farmers in the Mekong Delta to modify pest management and related practices through mass media. *International Journal of Pest Management 54* (4): 339-46.

Huelgas, Z.M., Templeton, D., and Castanar, P. 2008. Three Reductions, Three Gains technology in south Vietnam: Searching for evidence of economic impact. IRRI Social Science Division Working Paper, Los Baños.

Instituto Rio Grandense Do Arroz. 2011. Lavoura Arrozeira. Porto Alegre, Brazil, Vol. 64, No. 468 p. 28-32.

Instituto Rio Grandense Do Arroz. 2016. Lavoura Arrozeira. Porto Alegre, Brazil, Vol. 64, No. 468 p. 28-32.

Instituto Rio Grandense Do Arroz. 2017. Lavoura Arrozeira. Porto Alegre, Brazil, Vol. 65, No. 469 p. 26-29.

Instituto Rio Grandense Do Arroz. 2018. *Projeto 10+*. Uma Nova Etapa Para O Aumento Da Productividade No Cultivo De Arroz.

Instituto Rio Grandense Do Arroz., 2019, Lavoura Arrozeira. Porto Alegre, Brazil, Vol. 66, No. 470 p. 21-27.

Luat, N. V., Thanh, N. D., and Tam, B.T.T. 1998. Study on row seeding for rice production in the Mekong Delta, Vietnam. Omon, Rice Cuulong Delta Rice Research Institute, Vietnam, 6:147–151.

Menezes, V.G., Anghinoni, I., da Silva, P.R.F., M, V.R.M., Petry, C., Grohs, D.S., de Freitas, T.F.S., and Valente, L.A.L. 2013. *Projeto 10.* Management Strategies to Increase Productivity and Sustainability of Irrigated Rice Growth in the State of Rio Grande Do Sul, Brazil: Developments and New Challenges. Porto Alegre, Brazil.

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A., Chapoto, A., Asamoah, M., and Tripp, R.. 2013. Patterns of adoption of improved rice technologies in Ghana. IFPRI Working Paper, Washington, D.C.

Rodenburg, J. 2013. Inland valleys: Africa's future food baskets. In *Realizing Africa's Rice Promise*. Marco, C.S.W., Johnson, D.E., Ahmadi, N., Tollens, E., and Jalloh, A. (eds.). London: CAB International.

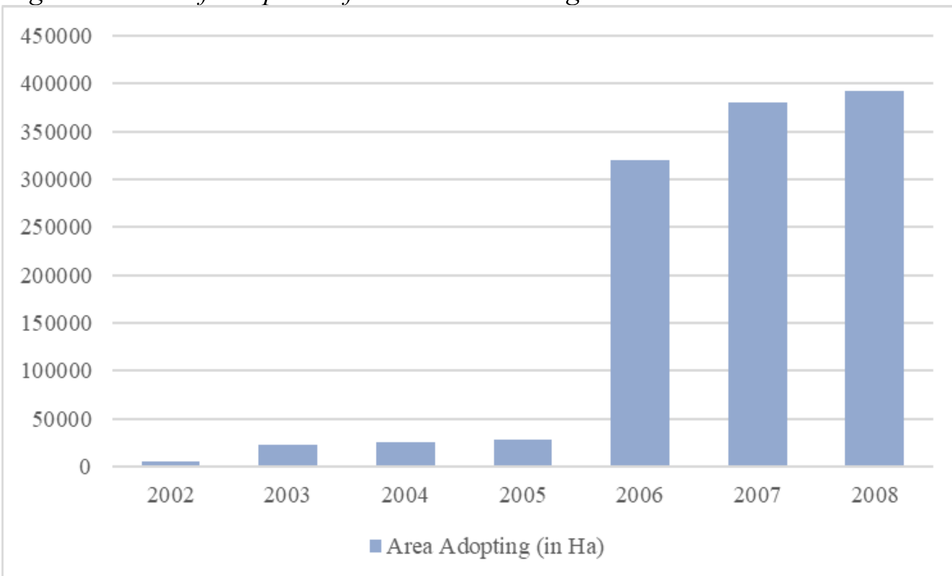
Singleton, G., Pha, D., An, N., Toan, N., Huan, N., Johnson, D., and Gummert, M. 2011. Applying good agricultural practices to increase rice production in the Mekong delta – the An Giang model. In *Hoi Thao Quoc Te – Con Duong Phat Trien Luq, Gao Chat Luong Cao Viet Nam*. Hanoi.

Singleton, G., and Nguyen, V.H. 2017. Vietnam sustainable agriculture transformation project: IRRI's contribution to component B: Supporting sustainable rice-based systems. Presented at VnSAT June 14, 2017. Khang Quang Do Hotel.

Takeshima, H., Y. Liu, C.V. Nguyen, and I. Masis. 2018. Evolution of agricultural mechanization in Vietnam: Insights from a literature review and multiple rounds of a farm household survey. IFPRI Discussion Paper: https://www.ifpri.org/publication/evolution-agricultural-mechanization-vietnam-insights-literature-review-and-multiple

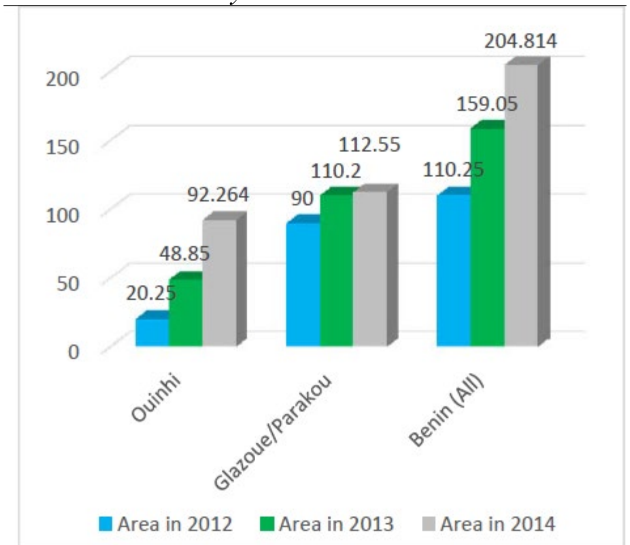
Zwart, S. 2014. Where is my technology going? Mapping of adoption of technologies and assessing diffusion pathways using geospatial technologies. Available https://smartiv. wordpress.com/. [accessed May 12, 2017].

Figure 1: Area of Adoption of 3R3G in An Giang Province



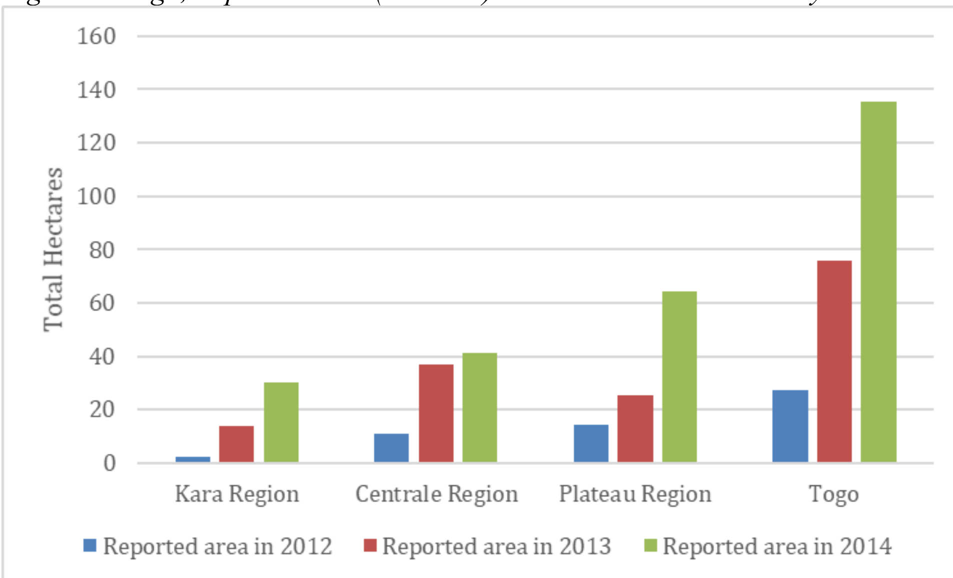
Source: Heong et al. (2010). Data from An Giang Department of Agriculture, Long Xuyen, Vietnam.

Figure 2: Benin, Reported Area (hectares) Under Sawah/Smart-Valley



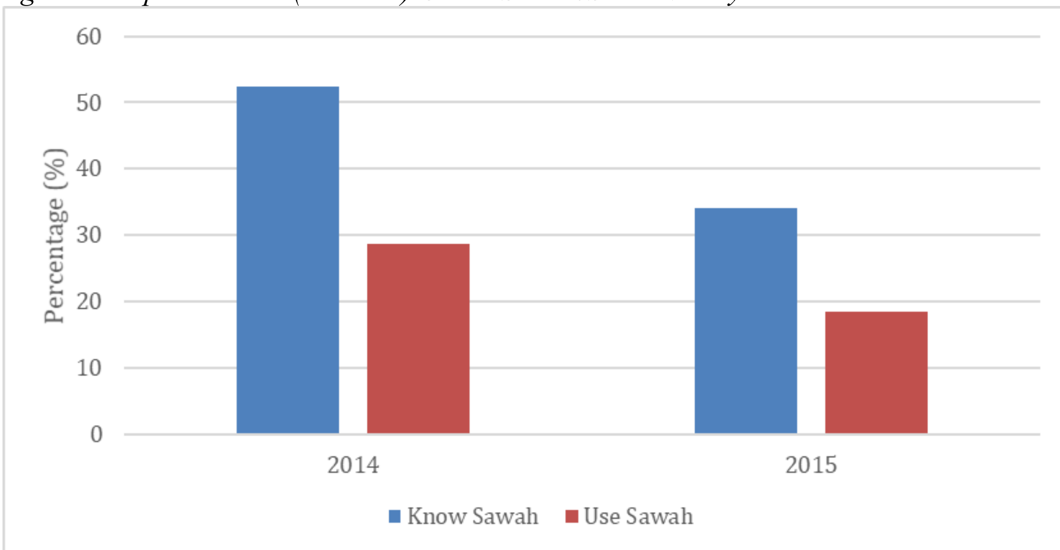
Source: Africa Rice Center (AfricaRice), 2015

Figure 3: Togo, Reported Area (hectares) Under Sawah/Smart-Valley



Source: AfricaRice (2015).

Figure 4: Reported Area (hectares) Under Sawah/Smart-Valley



Source: AfricaRice (2015).

Figure 5: Comparison of IRGA Monitoring Data and IRGA Census Data

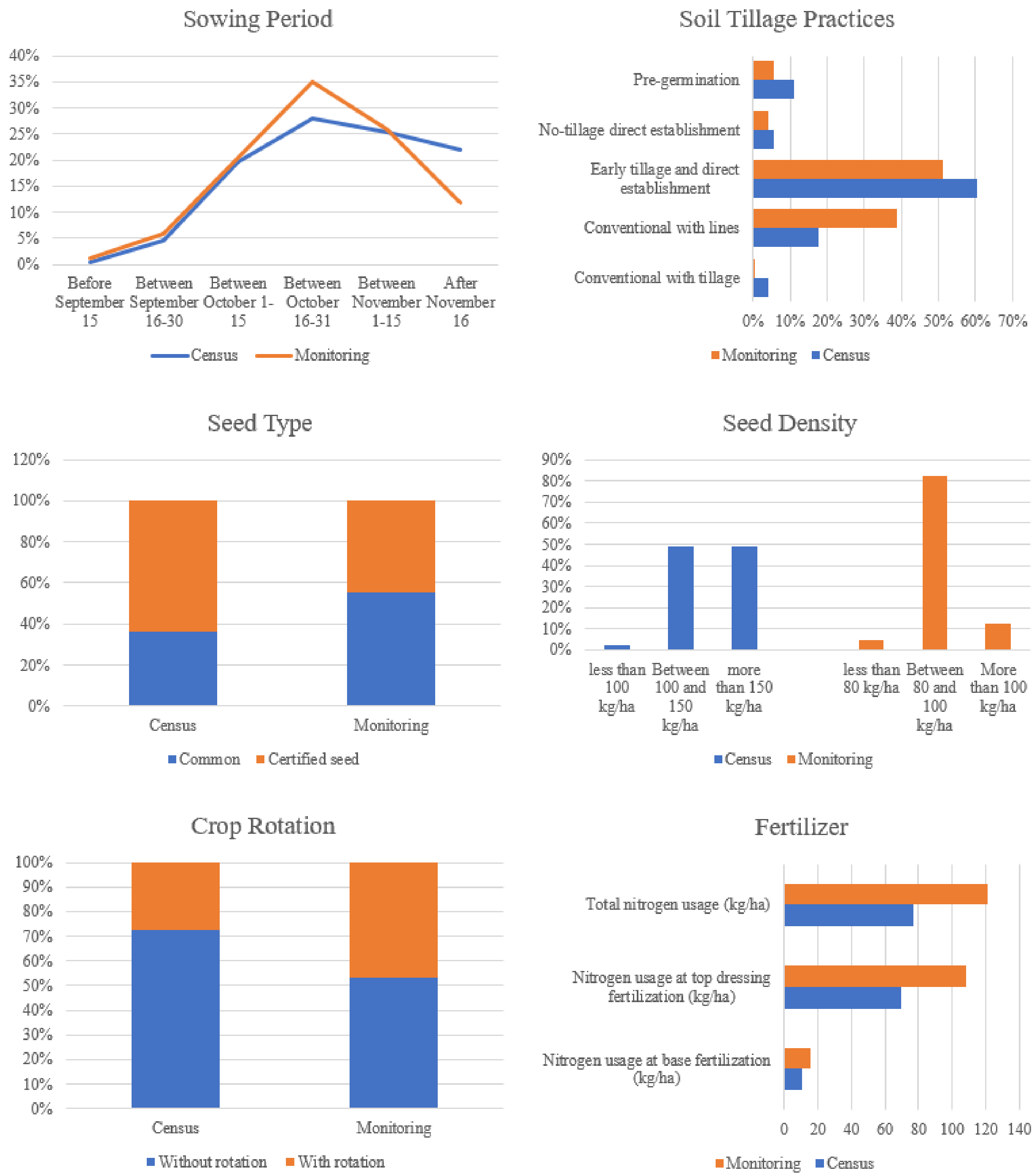


Table 1: Components of 3R3G and 1M5R

3R3G	1M5R
	Must use certified seed
Reduce seed rate below 100 kg/ha	Reduce seed rate below 100 kg/ha
Reduce fertilizer rate below 130 kg/ha of nitrogen	Reduce fertilizer rate below 130 kg/ha of nitrogen
Reduce pesticide applications below 4 per season	Reduce pesticide applications below 4 per season
	Reduce water use by applying AWD
	Reduce post-harvest loss by using combine harvester

Source: Huan et al. (2008).

Table 2: IRRI and VnSAT Dissemination Data 2017

	3R3G		1M5R	
	Cumulative May 2017	Cumulative August 2017	Cumulative May 2017	Cumulative August 2017
	Six Day Training			
No. Farmers (Ha)	32,619 (60,050)	48,324 (74,835)	-----	-----
Demo sites (Ha)	100 (128)	136 (145)	-----	-----
	Three Day Training			
No. Farmers (Ha)	12,065	15,245	8,594 (11,073)	10,024 (14,423)

Source: Singleton and Nguyen (2017).

Table 3: Dissemination and Adoption by VnSAT

Province	3R3G			1M5R		
	Farmers trained	Farmers Qualified	Hectares qualified	Farmers trained	Farmers qualified	Hectares qualified
Can Tho	24,103	14,872	18,296	13,633	8,330	10,745
Kiên Giang	14,991	7,048	15,644	8,199	5,748	11,522
An Giang	11,830	8,916	14,886	11,830	8,186	13,716
Dong Thap	22,231	13,339	20,338	21,537	12,492	19,385

Note: Data comes from the files of each Department of Agriculture and Rural Development (DARD) offices in each province. Data obtained in personal office visits by the authors.

Table 4: Fundamentals of Project 10

1	Sowing Period	This depends on factors such as weather conditions, soil type, weeds, cultivars, and the type of cultivation system. The crops reproductive phase should coincide with higher solar radiation, which occurs between mid-November and mid-February. Farmers should sow from September to November. Use cultivars that can tolerate lower temperatures and to sow at a depth of 2.0 cm.
2	Soil Tillage	Prior soil tillage is important to ensure high productivities. Recommended use of the minimum tillage system which involves the use of a broad-spectrum herbicide before crop cover develops.
3	Plant Nutrition	10-20 kg/ha of nitrogen fertilizer should be applied twice to dry soil sowing system. 2/3 of the fertilizer should be applied when the main stem has three to four leaves, and the rest should be applied in a water layer at the beginning of expansion of the first nod and main culm.
4	Water Management	Irrigation starts when the plant's main stem has three to four leaves. In this stage, rice plants are high enough to stand a water layer ranging from 5-10 cm. Start irrigation as early as possible and maintain the water at the same level.
5	Weed Control	For weed control, chemical control is the most efficient and affordable method to use. It is important to start chemical control once the plants have three to four leaves, before rice tillage and irrigation occurs
6	Cultivars	Cultivars that have unique characteristics and can be resistant to environmental stresses are highly recommended. The use of the Clearfield cultivars, for areas infested with red rice, is also emphasized.
7	Insects	Weed control is very important for pest management because infestations tend to appear where weeds are present. The use of chemicals should be used only when the number of insects reach significant levels.
8	Disease Management	General recommendations for disease management should be avoided. Chemical control should be focused on the prevention of diseases. A single application of fungicides should be enough to control diseases, but more can be used for those regions with a higher frequency of outbreaks

Source: Instituto Rio Grendense Do Arroz, 201

Table 5: Fundamentals of Project 10+

1	Planning	Ensuring efficient management practices, identifying potential constraints, defining the plan of action, and adapting current strategies and production systems.
2	Advanced Preparation	Making sure that you are planting during the adequate season or time.
3	Sowing Season	During this time, high productivity levels give you the opportunity to take advantage of environmental conditions for optimal plant growth.
4	Cultivating/Certified Seeds	The use of the recommended seeds guarantees the potential for higher yields. Using seed treatment maintains the quality of the seed until the land is ready for planting.
5	Density	Ensuring there is enough land to ensure high yields. 70-100 kg/ha is enough to hold 150-240 plants per meter square. Regulations are one of the reasons why there are inadequate establishments of land.
6	Fertilization	Should be based upon analyzing the soil, considering expected yields, the response from the cultivars, the growing season, and the history of the land.
7	Control of Harmful Plants	Should be based on current rotational practices, the history of the. Area, and the use of the recommended products. Importance is put upon irrigation and crop rotation as a tool to maintain a good control over harmful plants.
8	Mulching	Under ideal circumstances, it is recommended that most of the dose be applied on dry soil during phases V3-V4, immediately preceding irrigation.
9	Irrigation Management	Delaying irrigation is one of the limiting factors for a high yield. This step should be applied in the V3-V4 stages after applying urea fertilizer and after treating for harmful plants. Under adequate conditions, this ensures the effectiveness of the other management steps.
10	Integrated Disease and Plague Management	Determined by those crops resistant to diseases, history of the area, monitoring of the areas, assessing economic damage, and if necessary, the use of recommended problems to solve the infestation.

Source: IRGA Uma Nova Etapa, 2013.

Table 6: Project 10 Trainings

Growing Season	Agronomists	High School Level Technicians	Farmers and Workers	Total
2003/04	115	67	464	606
2004/05	145	75	2,370	2,590
2005/06	150	80	1,313	1,542
2006/07	155	80	1,850	2,085
2007/08	50	63	2,720	2,883
2008/09	62	46	3,796	3,904
2009/10	67	47	1,357	1,471
2010/11	71	49	1,798	1,918
Total	815	507	15,627	16,949

Source: IRGA Projeto 10 Management Strategies, 2013.