MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE SCIENTIFIQUE
****
UNIVERSITÉ DES SCIENCES, DES TECHNIQUES ET DES TECHNOLOGIES DE BAMAKO (USTTB)
****
ÉCOLE DOCTORALE DES SCIENCES ET TECHNOLOGIES DU MALI (EDSTM)

RÉPUBLIQUE DU MALI
****
Un Peuple - Un But - Une Foi

DOCTORATE THESIS

TITLE

SYSTEM OF RICE INTENSIFICATION (SRI) ADOPTION CHALLENGES AND PERSPECTIVES IN THE CONTEXT OF CLIMATE CHANGE IN MALI: A CASE STUDY OF SÉLINGUÉ AND BAGUINÉDA IRRIGATED SCHEMES

A thesis, submitted to the University of Sciences, Techniques and Technologies of Bamako (USTTB), in partnership with the Rural Polytechnic Institute of Trainings and Applied Research (IPR/IFRA) of Katibougou and the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL),
in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy (Ph.D.) in Climate Change and Agriculture

Presented and defended on: 20/11/2025
By Mr Mohamed SIDIBE

JURY
President: *Mr Yacouba DIALLO, Full Professor, IPR-IFRA of Katibougou, Mali*
Members
Examiner: *Mr Alou Badra KOUYATE, Associate Professor, IPR/IFRA, Mali*
Reporter: *Mr Aly KANSAYE, Associate Professor, IPR-IFRA of Katibougou, Mali*
Reporter: *Mr Souleymane Sidi TRAORE, Associate Professor, FHG/USSGB, Bamako, Mali*
Director: *Mr Mohamed Dicko, Research Director, IER, Bamako, Mali*
Co-Director: *Mr Amadou SIDIBE, Associate Professor, IPR-IFRA of Katibougou, Mali; Mr Elliott Dossou-Yovo, Senior Scientist, Africa Rice Centre, République de Côte d'Ivoire*

SYSTEM OF RICE INTENSIFICATION (SRI) ADOPTION CHALLENGES AND PERSPECTIVES IN THE CONTEXT OF CLIMATE CHANGE IN MALI: A CASE STUDY OF SÉLINGUÉ AND BAGUINÉDA IRRIGATED

BY

Mohamed SIDIBE

MSc. Climate Change and Adapted Land Use

MSc. Environmental Management

November 2025

Certification

a) By the student:

I hereby declare that this thesis has not been presented elsewhere for the award of any degree, or any other purposes.

Candidate's Name:…….....**Mr Mohamed SIDIBE** ……...

Signature:…… ……..... **Date:** ……**19 / 04 / 2025** ….…….

b) By the supervisor(s):

I (we) certify that this work has been carried out by Mr Mohamed SIDIBE under my (our) supervision and that to the best of my (our) knowledge, it has not been submitted elsewhere for the award of a degree.

Supervisors' Names

Major supervisor: …… **Dr Mohamed DICKO** ……..……

Signature: **Date** …… **28 / 04 / 2025** ……..……....

Co-supervisor: ……..**Dr Elliott Dossou-Yovo** ……..……..

Signature: **Date:** ……....… **28 / 04 / 2025** . ……..……

Co-supervisor: ……...**Dr Amadou SIDIBE** ……..……..…….

Signature: **Date:** ……....… **21 / 04 / 2025** ..……..……

Director of Postgraduate School (EDSTM): ……**Prof. Bakary MAIGA**……...……..

Signature:……. **Date:** ……..… / ……../ **2025** ..……

Table of contents

Certification i

Table of contents ii

Dedication vi

Acknowledgements vii

List of acronyms and abbreviations ix

List of Tables xi

List of Figures xii

Résumé xiii

Abstract xiv

CHAPTER ONE 1

1.0. INTRODUCTION 1

1.1. Background to the study 1

1.2. Statement of the problem 2

1.3. Justification for the study 4

1.4. Research questions 5

1.5. Hypotheses 6

1.6. Aim and objectives of the study 6

1.6.1. Aim 6

1.6.2. Specific objectives 6

1.7. Scope and limitations of the study 7

1.8. Outline of the thesis 7

CHAPTER TWO 9

2.0. LITERATURE REVIEW 9

2.1. Review of Concepts 9

2.1.1. Technology in agriculture 9
2.1.2. Adoption of a technology 9
2.1.3. Climate change 10
2.1.4. Climate variability 10
2.1.5. Adaptation to Climate Change 11
2.1.6. Ecosystem-based Adaptation (EbA) 11
2.1.7. Evolutionary adaptation 11
2.1.8. Incremental adaptation 11
2.1.9. Transformational adaptation 11
2.1.10. Adaptation limits 12
2.1.11. Adaptation options 12
2.1.12. Adaptive capacity 12
2.1.13. Maladaptive actions (Maladaptation) 12
2.1.14. Mitigation of Climate Change 12
2.2. Literature Review 13
2.2.1. The System of Rice Intensification, Origin and Principles 13
2.2.2. Introduction and spreading of SRI in West Africa and Mali 14
2.2.3. SRI attributes and challenges vs conventional practice 15
2.2.4. Technology adoption in agriculture 16
2.2.5. Technology adoption factors / SRI adoption determinants 17
2.2.6. SRI adoption evaluation approaches 20
CHAPTER THREE 23
3.0. RESEARCH METHODOLOGY 23
3.1. Study area 23
3.1.1. Choice of the study sites 23

3.1.2. Climate 23

3.1.3. Economic activities 24

3.1.4. Organisation of the labour in Sélingué and Baguinéda 25

3.1.5. Presentation of Selingué and description of the irrigated scheme 25

3.1.6. Presentation of Baguinéda and description of the irrigated scheme..... 28

3.1.7. Management of the irrigated schemes 31

3.2. Data 33

3.2.1. Questionnaire 34

3.2.2. Sampling 35

3.2.3. Experiment 36

3.2.3.1. Description 36

3.3. Data analysis 38

3.3.1. Adoption level of SRI principles 38

3.3.2. Factors determining the adoption or non-adoption of the SRI principles 38

3.3.2.1. Pearson's Chi-square test for independence..... 39

3.3.2.2. Mann-Whitney U test..... 40

3.3.3. Technical, technological and managerial conditions enabling or hindering the application of SRI principles 41

CHAPTER FOUR..... 42

4.0. RESULTS AND DISCUSSION 42

4.1. Results 42

4.1.1. Socio-economic description, location and group differences 42

4.1.1.1. Socio-economic description of Baguinéda and Sélingué farmers..... 42

4.1.1.2. Location and group differences..... 45

4.1.2. Adoption level of different SRI principles 49

4.1.2.1. Adoption rates of different principles 49

4.1.2.2. Adoption depth of SRI 50

4.1.3. Factors determining the adoption or non-adoption of SRI principles at farmers' level 52

4.1.3.1. Motivation for practicing SRI 52

4.1.3.2. Constraints to practicing SRI 53

4.1.3.3. Relationship between SRI adoption and different factors 55

4.1.3.3.1. Factors associated with SRI practice 55

4.1.3.3.2. Factors associated with different SRI principles 62

4.1.4. Technical, technological and managerial conditions enabling or hindering the application of SRI principles 67

4.1.4.1. Partnership, advisory service and awareness delivery 67

4.1.4.2. Physical conditions of the schemes 69

4.1.4.3. Management of the schemes 70

4.1.4.4. Social and financial capacities 71

4.2. General discussion 72

CHAPTER FIVE 76

5.0. CONCLUSION AND RECOMMENDATIONS 76

5.1. Conclusion 76

5.2. Recommendations 77

REFERENCES 79

ANNEXES xv

Dedication

In recognition of the devotion and efforts of my dear uncle Amadou Sidibé, because of whom this was possible

Acknowledgements

To the Creator, I am grateful, always, sincerely and deeply. To Him is due all praises, at any time and under any circumstances.

To my major supervisor Dr Mohamed Dicko, Research Director at the Institute for Rural Economy (IER), Mali, I am deeply grateful for his invaluable scientific contributions to this thesis and for all the guidance he provided. I am also very grateful to my co-supervisor Dr Elliott Ronald Dossou-Yovo, Senior Scientist at Africa Rice Centre, Republic of Côte d'Ivoire, for highly contributing to this work. Special recognition to my co-supervisor Dr Amadou Sidibé, Associate Professor at the Rural Polytechnique Institute for Trainings and Applied Research (IPR-IFRA) of Katibougou, for his devotion, scientific contributions and investments, including financial, from the very beginning to the end. His devotion is the very reason this journey continued.

I express my gratitude to the Doctoral School of Sciences and Technologies of Mali / *Ecole Doctorale des Sciences et des Technologies du Mali* (EDSTM) and the Rural Polytechnique Institute for Trainings and Applied Research (IPR-IFRA) of Katibougou, the heads, lecturers and all staff members of these institutions, for granting me admission and providing an adequate environment for learning and research.

I am grateful to the outgoing Director of the Doctoral Research Programme in Climate Change and Agriculture (DRP CC-Agric), Prof. Yacouba Diallo, for his support, encouragement and patience. I am also thankful to the WASCAL Mali staff, Dr Amadou Coulibaly (new Director) and Dr Kaboro Samassé for their encouragement, facilitation and mentorship all the way along.

I recognise the assistance and facilitation of all staff members, field technicians and farmers involved from both Baguinéda and Sélingué irrigated schemes. I salute them for accepting this study in their respective locations, providing information without which our objectives could not have been reached.

I thank all my colleagues for their support and encouragement. We spent a great time together.

I specially salute the memory of my beloved father, the love and prayers of my adorable mother, the love and patience of my wife and the love of my children. These positive energies shine my life of everyday. I thank The Creator for it all.

My sincere appreciation goes to the German Federal Ministry of Education and Research (BMBF) and the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) for providing me this PhD scholarship.

List of acronyms and abbreviations

AWD	Alternate Wetting and Drying
CF	Continuous Flooding
CGCM	Canadian Global Circulation Model
CH4	Methane
CIIFAD	Cornell International Institute for Food, Agriculture and Development
CIV	*Centre d'Innovations Vertes* / Green Innovation Centre
DAT	Day After Transplanting
EbA	Ecosystem-based Adaptation
FAO	Food and Agriculture Organisation of United Nations
FBO	Farmer-Based Organisation
FFS	Farmer Field School
FGD	Focus Group Discussions
FSA	Farmer School Approach
GDP	Gross Domestic Product
GHG	Green House Gas
GIZ	German Society for International Cooperation
Gt	Giga tonnes
HadCM	Hadley Coupled Model
IER	*Institut d'Economie Rurale* / Institute for Rural Economy
IPCC	Intergovernmental Panel on Climate Change
LABOSEP	*Laboratoire Sol-Eau-Plante* / Soil-Water-Plant Laboratory
MES	*Ministère de l'Environnement et la Santé* / Ministry of Environment and Health
N_2O	Nitrous Oxide
NGO	Non-Government Organisation
NPK	Nitrogen Phosphorus and Potassium
ODRS	*Office de Développement Rural de Selingué* / Sélingué Rual Development Office

OERHN	*Office pour l'Exploitation des Ressources Hydrauliques du Haut Niger/* Office for the Exploitation of Upper Niger Hydraulic Resources
OPIB	*Office du Périmètre Irrigué de Baguinéda / Office for Baguineda Irrigated Scheme*
RCP	Representative Concentration Pathways
SRI	System of Rice Intensification
SSWA	Sub-Saharan West Africa
UNFCCC	United Nations Framework Convention on Climate Change

List of Tables

Table 3.1: Equipment scoring 39

Table 4.1: Ratio Equipment versus producers 44

Table 4.2: Difference between Baguinéda and Sélingué farmers I 46

Table 4.3: Difference between Baguinéda and Sélingué farmers II 47

Table 4.4: Difference between adopters and nonadopters I 48

Table 4.5: Difference between adopters and nonadopters II 49

Table 4.6: Adoption rate of the principles 50

Table 4.7: Adoption depth of the core principles 51

Table 4.8: Adoption depth of the six principles 51

Table 4.9: Proportion of land allocated to SRI 51

Table 4.10: Average rice plot size versus SRI allocation (ha) 52

Table 4.11: Motivation for applying SRI 53

Table 4.12: Reasons for not applying SRI 54

Table 4.13: Chi-Square Tests Results 55

Table 4.14: Mann-Whitney U results 57

Table 4.15: Gender-based differences 59

Table 4.16: Factors and principles' interaction 66

List of Figures

Figure 3.1: Study area and agroecological zones in Mali. 24

Figure 4.1: Education level in Baguinéda and Sélingué 43

Figure 4.2: Age distribution of the respondents 44

Figure 4.3: Factors and principles' Network 65

Résumé

Le Système de Riziculture Intensive (SRI) a été introduit au Mali depuis une décennie, pour accroître la production rizicole et répondre aux problèmes d'eau. Cependant, depuis son introduction, aucune évaluation n'a été réalisée. Cette étude visait à examiner le niveau d'adoption du SRI, identifier les facteurs déterminant son adoption ou sa non-adoption et les conditions techniques, technologiques et de gestion favorisant ou entravant l'application des principes du SRI à Baguinéda et Sélingué. Une enquête a été menée auprès de 121 agriculteurs, complétée par des *focus group* et des entretiens avec des informateurs clés. La première étape de l'analyse des données a consisté à utiliser les fréquences et les pourcentages pour déterminer les facteurs motivant ou entravant la pratiques du SRI, ainsi que les différentes caractéristiques des adoptants et des non-adoptants. Dans la deuxième étape, nous avons étudié la relation entre l'adoption du SRI et différents facteurs en utilisant le *Person's Chi-square Test* d'indépendance et le *Mann-Whitney U test*. Parmi les quatre principes fondamentaux du SRI, les plus largement pratiqués sont l'écartement large (92%) et le repiquage en un plant par poquet (73%), tandis que le repiquage précoce et l'alternance d'irrigation et d'asséchement ne sont pratiqués que par la moitié des adoptants (42 à 52%). À l'exception de l'écartement large, les autres principes ont été appliqués plus largement à Baguinéda qu'à Sélingué. Globalement, les agriculteurs de Baguinéda ont appliqué davantage de principes et alloué plus de terres au SRI que ceux de Sélingué. Les motivations pour l'adoption du SRI étaient l'augmentation du rendement, l'économie de semences, le tallage, la qualité des grains, la facilité du travail au champ, l'efficacité de l'utilisation des engrais, l'efficacité de l'utilisation de l'eau et la croissance rapide des plantes. Les contraintes comprenaient le coût élevé du repiquage, les besoins en main-d'œuvre, la maîtrise de l'eau, les connaissances, les engrais organiques, l'investissement dans la préparation du sol, les engrais chimiques. Les facteurs déterminant l'adoption du SRI sont le niveau d'éducation (formel), le sexe, l'appartenance à une organisation d'agriculteurs (OPA), l'implication dans des projets, la manière dont les agriculteurs ont découvert le SRI, la facilité d'accès à l'eau, l'accès au crédit, la taille du ménage et des terres, la main d'œuvre, la taille de l'exploitation rizicole et le niveau d'équipement. De plus, l'état des infrastructures des périmètres irrigués et leur gestion jouent un rôle important dans l'adoption du SRI. À cet égard, l'adoption du SRI est une dynamique complexe et spécifique au contexte. Par conséquent, les stratégies visant à promouvoir le SRI dans des contextes similaires ne devraient pas uniquement se limiter à la sensibilisation des agriculteurs, de telles stratégies devraient plutôt inclure des composantes portant sur l'environnement biophysique, technique, technologique et managérial.

Abstract

The System of Rice Intensification (SRI) was introduced in irrigated schemes in Mali, a decade ago, to increase rice production and address water scarcity challenges. However, since its introduction, no evaluation has been conducted. This study aimed to investigate the adoption level of the SRI principles, identify the factors determining its adoption or non-adoption and identify the technical, technological and managerial conditions enabling or hindering the application of the SRI principles in Baguinéda and Sélingué. A survey was conducted with 121 farmers from Baguinéda and Sélingué, supplemented by focus group discussions and key informant interviews. The first step of the data analysis consisted of using frequencies and percentages to determine the factors motivating or preventing SRI practices, and the different characteristics of SRI adopters versus nonadopters. In the second step, we investigated the relationship between SRI adoption and different factors using the Person's Chi-square Test for independence and the Mann-Whitney U Test. Among the SRI four core principles, the most widely practiced in both schemes were wide spacing (92%) and single seedling (73%), while early age transplanting and alternate wetting and drying were practiced by only half of the adopters (42 – 52%). Except for the wide spacing, the other principles were applied more extensively in Baguinéda than in Sélingué. Overall, farmers in Baguinéda applied more principles and allocated more land to SRI than in Sélingué. The main motivations for adopting SRI were yield increase, seeds economy, increased tillering, improved grain quality, easy field work, fertilizer use efficiency, water use efficiency and rapid plant growth. The major constraints included high transplanting cost, increased requirements for labour, water control, knowledge, organic fertilizer, investment for land preparation, chemical fertilizer and a compelling agenda. The factors that determine SRI adoption were the education level (formal), gender, membership of a FBO, involvement with projects or NGOs, the way farmers discovered SRI, easy access to irrigation water, credit access, the size of the household, the total number of household labour, the number of females above fifteen years old, the total household members above fifteen years old, the size of the rice farm, the total land owned by the household and the equipment level. In addition, the infrastructural conditions of the irrigated schemes and their management play an important role in the adoption of the SRI. In this regard, the adoption of SRI is a complex dynamic and context specific. Therefore, strategies aiming at promoting the SRI in similar contexts, should not be limited to educating famers on how SRI works. Such strategies should rather include components addressing other aspects including biophysical, technical, technological and managerial environment.

CHAPTER ONE

1.0. INTRODUCTION

This chapter informs of background of the study, indicates the context and the problem that justifies the study. It also contains the hypotheses, the research questions and objectives that emanate from the stated research problem and context. Finally, it contains the scopes and limitations of the study and the thesis outline.

1.1. Background to the study

Generality on agriculture in Mali

As in many other Sub-Saharan West African (SSWA) countries, agriculture is the main source of income for the Malian population. It employs more than 70% of the population and contributed about 40 % to the Gross Domestic Product (GDP) in 2015, and the main food crops in terms of production are rice, millet, maize and sorghum, while cotton is the main industrial cultivated crop (FAO, 2017).

In Mali, agricultural activities are diversified across the agroecological zones of the country. Southern regions receive more rain than central and northern regions. Rainfed Crop production is therefore dominant in southern areas where most of the country's population is concentrated.

The hugeness of Mali's landmass endows the country with large arable lands (12.2 million ha), and a great deal of space for animal rearing (30 million ha of grazing land) (Clemence, 2015).

In addition, two major rivers pass through the country, the Niger and Senegal rivers with a total of 2 600 km, granting the country with 2.2 million ha suitable for irrigation (Clemence, 2015). Despite this huge endowment with irrigable lands, only around 20% is currently under irrigation (Clemence, 2015). That makes the agricultural production mainly dependent on rainfall regime for all the main crops except for rice production systems which depends on both. Indeed, most of the rice produced nationally is from irrigated systems.

Climate change and agriculture

Climate and agriculture interact with each other. While climate parameters determine agricultural production, some agricultural production systems can contribute to more emission of greenhouse gases and thereby impact on climate. For example, agricultural intensification has for long been a slow process in most African countries (Binswanger-Mkhize, 2017), increases in agricultural production were mostly done through deforestation and expansion of agricultural lands instead of improved technologies, practices, fertiliser application and improved seeds. That has been the primary phenomenon leading to forests loss, shrinking of pasture lands and degradation of soils, which thereby aggravate climate change. In addition, the amount and distribution of rainfall determine rice yields during the rainy season as well as the amount of available water resources (surface and groundwater) for the off-season period.

In Africa, studies have shown that agricultural activities emitted between 0.44 Gt and 0.54 Gt CO_2 equivalent in 1994, 0.66 Gt and 0.79 Gt in 2010 and a total of 0.87 Gt in 2014 with 20% of the total emissions from West Africa, and the rice production accounts for 3.7% of agricultural emissions in the continent (Tongwane and Moeletsi, 2018). In West Africa, Mali, Burkina Faso and Niger are the countries with the highest greenhouse gas emission intensities, and between 1994 and 2010, the contribution of rice production to total agricultural CH_4 emissions has been 17% during the period (Tongwane and Moeletsi, 2018). Two-thirds of GHG emissions from the agriculture sector in Africa are from CH_4 and a third is from N_2O (Tongwane and Moeletsi, 2018). The highest emissions from rice production are in tropical West Africa (Carlson et al., 2016). GHG emissions from crops in most parts of Africa are predominantly from fertilizer applied during rice and maize productions (Sheahan and Barrett, 2017), and water management systems (continuous flooding).

1.2. Statement of the problem

Mali has been experiencing an increase in temperature for a long time (Butt et al., 2005) and significant variability and predicted changes in weather parameters including temperature has also been documented. Bodegom and Satijn (2015) stated that Mali is characterised by frequent droughts, annual rainfall variability and that local temperatures,

rainfall variability and the extent of severe weather events are expected to increase due to climate change.

Decreasing trend of rainfall coupled with higher temperatures trend have been documented across Mali. The National Directorate of Meteorology (2001) depicted decreases in the rainfall trend from 1961 to 2001. Bodegom and Satijn (2015) reported that in the 1950s', the annual precipitation used to vary within the range 500 and 1500 mm but in the course of the last 15-20 (1995-2015) years the maximum has not been beyond 1300 mm.

Climate variability and change are challenges that the Malian agriculture will continue facing. Climate projections predict decreases in precipitation and increases in temperature. Precisely, the Canadian Global Circulation Model (CGCM) and the 2030 projections of the Hadley Coupled Model (HadCM) indicate that the average temperature in Mali might rise by about 1– 2.75 °C, with precipitation decreasing slightly (Butt et al., 2005).

In addition to these climatic conditions, the population growth coupled with land degradation threaten the country's ability to produce more food to feed the future populations. A study over Africa, conducted by van Oort et al. (2017) reports that with current rice varieties, negative impacts on rice yields are to be expected in 2070 under RCP 2.6, 4.5, 6.0 and 8.5 scenarios. The study also highlights that irrigated rice yields in the hot dry season is likely to significantly decrease due to reduced photosynthesis, in West Africa.

Indeed, this implies more risk and uncertainty for agricultural production and food security, especially in Mali where irrigated systems represent the main bowl of rice production. Therefore, it is urgent to develop and promote agricultural production options that can adapt agriculture to current and future climate impacts, produce more food and reduce greenhouse gas emissions if possible (climate-smart agriculture). The System of Rice Intensification (SRI) seems to fulfil these requirements as reported by different authors from several places around the world (Kimura, 2009; Karki, 2010; Anas et al., 2008, 2011a, 2011b; Choi et al. 2012, 2014; Dill et al. 2013; Gathorne-Hardy et al., 2013; Kamabara et al. 2013; Uphoff, 2016). In fact, promoting irrigation practices, could help reduce the risks associated with rainfall dependency. It is in this perspective that the SRI has been introduced in Mali. Since the SRI introduction in Mali, no studies have been

conducted to understand how the SRI evolved in the context of the country. This justifies the current study as detailed in the next section.

1.3. Justification for the study

Mali is the second biggest rice producer in West Africa, after Nigeria, and rice contributes to around 5% to the GDP, and about 9% of the agricultural share to the GDP, and represents 30% of produced cereals (FAO-APRAO, 2013; DGICD, 2017). The country is endowed with huge capabilities for rice production with a potential of 2.2 million ha of irrigable land, of which only around 20% is currently under irrigation (Clemence, 2015).

Four major rice production systems which are lowlands partially controlled flooding, full water-controlled irrigation, rainfed and uncontrolled river flooding exist in the country. These systems of irrigation occupy respectively 45, 25, 18 and 12% of the total rice production area (DGICD, 2017).

Annual rice production in Mali has increased from 20 000 t in early 1980s to 1 million t in early 2000s, and to 2.2 million t in 2018 (FAOSTAT, 2020). Accordingly, rice production area has been substantially increasing since 1960. From 1961 to 2018, the production area has almost been tripled, going from 180 000 to 6 466 694 ha. These increases in production area and quantity are meant to meet the increasing rice demand which is as a result of population growth and change in diets as justified by a per capita consumption that went from 13 kg per year in 1960 to 84 kg in 2009 (FAO-APRAO, 2013). The production area increase led to increase in national rice production. However, in 2009, 45 % of rice available on national market was imported, while the importation for the entire West Africa was 40% (FAO-APRAO, 2013). This importation is mainly from Asia.

In order to meet the increasing national demand for rice consumption, and to ensure rice self-sufficiency by limiting importation, more increase in rice production area as it has been the case in recent years should be expected. This implies more GHG emissions since it is established that rice production is one of the major GHG sources in agricultural sector (Linquist et al., 2012; Vetter et al., 2017; Tongwane and Moeletsi, 2018). Therefore, there is need to increase rice production while limiting GHG emissions through climate-smart agriculture technologies to prevent more negative impacts of climate change.

The SRI which originated from Madagascar and widely used across the world, mainly in Asia is known to increase rice yield by using less water resources (up to 75% of water use efficiency), chemical fertilizer (Uphoff, 2016), and emitting less GHG, precisely CH_4 as reported in several studies across Asia (Anas et al., 2008; Kimura, 2009; Karki, 2010; Choi et al., 2012, 2014; Dill et al., 2013; Gathorne-Hardy et al., 2013; Uphoff, 2016). These studies have investigated the capabilities of the SRI to reduce GHG emissions from rice fields, and different results have been produced. While all the results indicated net decrease in CH_4 emission, more or less increase in N_2O emission were also noticed, which brings the need to investigate the trade-off.

On the course of its expansion globally (Katambara et al., 2013; Noltze et al., 2013) upon its successes, SRI has been introduced in West Africa in recent years (Uphoff, 2016). On the basis of the seemingly more or less favourable comments on its added value, the Government of Mali with some partners has elaborated the National Ten-Year Scaling Up Programme for the System of Rice Intensification (PN-SRI). However, it should be noted that apart from some framed and purely agronomic pre-dissemination trials, no science-based study was conducted in Mali to investigate and (1) determine the adoption level of the SRI principles, (2) identify the factors determining the adoption or non-adoption of the SRI at farmers' level, (3) identify the technical, technological and managerial conditions favouring or hindering the application of the SRI principles in the study area. This study aims to fill that gap.

1.4. Research questions

The above problem statement brings us to formulate the following main research question: How is SRI practiced and what are the adoption perspectives in the context of climate change in Mali?

Specific questions

This main research question is split into the following specific questions:

1. What is the adoption level of the SRI principles since its introduction?
2. What are the factors determining the adoption or non-adoption of SRI at farmers' level?

3. What are the technical, technological and managerial (institutional framework) conditions enabling or hindering the application of SRI principles in the study areas?

1.5. Hypotheses

With the above questions and based on the observation of selective application of the SRI principles by farmers and their tendency to adapt them to their specific conditions, we formulated the hypotheses below:

1. The adoption or non-adoption of the SRI principles depends to some extent on the biophysical conditions of the area;
2. The socioeconomic status of the farmers can determine the adoption of some SRI principles;
3. The institutional arrangement and governance of the irrigated schemes as well as the technical and technological conditions influence the adoption of some SRI principles.

1.6. Aim and objectives of the study

1.6.1. Aim

This study aims at producing scientific information that could inform the SRI adoption process with the ultimate goal of contributing in reducing climate chance advert impacts on agriculture in Mali.

1.6.2. Specific objectives

The abovementioned aim is to be achieved through the following specific objectives:

1. Determine the adoption level of the SRI principles;
2. Identify the factors determining the adoption or non-adoption of the SRI at farmers' level;
3. Identify the technical, technological and managerial (institutional framework) conditions enabling or hindering the application of the SRI principles in the study area.

1.7. Scope and limitations of the study

Based on the proven water saving advantage and the high yield potential of the SRI, this study addresses its adoption level, factors and different technical, technological and managerial enablers and/or constraints in Mali. It does not investigate the GHG emission reducing potential of the SRI in the Malian rice production areas but will assume it beneficial, at least in terms of methane emissions.

1.8. Outline of the thesis

This outline gives indications on what the different chapters of the thesis contains and how they are structured as a whole.

Chapter I is the introduction chapter. It informs of background of the study, indicates the context and the problem that justifies the study. It also contains the hypotheses, the research questions and objectives that emanate from the stated research problem and context. Finaly, it contains the scopes and limitations of the study and the thesis outline.

Chapter II is the literature review chapter. Under this chapter, the mains concepts that pertain to our study are defined in the first section. The second section contains the review of the literature related to different major topics of our study on the SRI, its origins and principles, introduction and spreading in West Africa and especially in Mali, its attributes and challenges compared to conventional practice, technology adoption in agriculture, technology adoption factors and SRI adoption determinants and its adoption evaluation.

Chapter III presents the study area, mentions the reasons that justifies their choice. It also describes the data required to answer the different research question and their collection process. Finaly, it describes the methodologies that were used to answer each research questions of the thesis.

Chapter IV contains in its first section, the presentation of the results of the different analyses conducted and the direct discussion of some results-where appropriate. This first section highlights what our analyses brought to light. The second section contains the general discussion of all the results. It informs of the understanding to be obtained from the statistics, figures and tables contained in the results section. It also mentions their significance, utility and limitations.

Chapter V contains the conclusion that could be drawn from the study and the recommendations whose implementation we think can improve the adoption level of the SRI in the two locations and other locations with similar context.

CHAPTER TWO

2.0. LITERATURE REVIEW

This chapter of the thesis defines the concepts used in this study and some most used concepts in climate change field, and presents a review of related studies in accordance with the different topics.

2.1. Review of Concepts

2.1.1. Technology in agriculture

Technology or innovation in agriculture (interchangeable in this thesis) refers to any product, service, technique or practice including the instruments and tools required by such product, service, technique or practice that is new or recent to the population it is being presented to. The ultimate aim of technology is to increase the efficiency and profitability through better use of inputs and more outputs. It is generally developed deliberately-from coordinated research or undeliberately-from long years evolution in practices by farmers for example, like the case of SRI as documented by Laulanie (1993). In either case, the aim is to overcome a known or potential challenge.

2.1.2. Adoption of a technology

The adoption of a technology has been defined by Rogers (2003) as the decision to make full use of an innovation. That definition would be full and complete if the technology referred to is a single action, like improved seeds adoption for example, in which case the farmer simply decides to use it or not. However, in most cases technologies come as packages of actions. The SRI is one of such cases. Indeed, it is a set of actions that can be adopted altogether or separately. This brings out the concept of partial adoption, which refers to the adoption of one or more principles of a technology without adopting the others. Furthermore, to understand the underlying processes that may enable or constrain the take-off and the sustainability of a technology, other studies consider technology as a socio-technical phenomenon (Sidibé et al., 2021). This substantiates the importance of understanding the biophysical, social, institutional and technological dimensions of SRI adoption in Mali.

2.1.3. Climate change

Climate change is differently defined by the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC). While the IPCC makes inclusion of both natural and human factors as causes of changes in climate (mean and/or variability of its properties) for an extended period of time, the UNFCCC defines it by focusing on the human activity causing direct or indirect changes in climate over long periods of time added to natural climate variability (IPCC, 2007). The latter excludes the natural factors as causes of change. Though they differ in including natural variability, both of them agreed that it should be over a long period of time (a minimum of thirty years). That suggests that at least three decades of statistical data are required for studies aiming at showing evidence of climate change. In this regard, Adhikari et al. (2011) mentioned that 'It refers to a statistically significant variation in either the mean state of the climate or in its change, persisting for an extended period (typically decades or longer)'.

2.1.4. Climate variability

Climate variability refers to variations in the mean state and other climate statistics (standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond those of individual weather events (Adhikari et al., 2011). Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forces (external variability).

Climate variability and changes and their consequences are worldwide (IPCC, 2007), and Mali is not an exception. Indeed, in addition to seasonal variabilities, an increase of 0.7 °C in temperature over the period (1960-2001) has been reported (Butt et al., 2005). Furthermore, future projections of climate in Mali are worrisome. Projected changes in mean annual rainfall range from -22 to +25 % by the 2090s, depending on 'wet' or 'dry' scenarios with the most likely change between 0 and -11 % (Bodegom and Satijn, 2015). These changes in temperature and rainfall though the latter not precise, establish the evidence of climate change and variability occurrence in Mali.

2.1.5. Adaptation to Climate Change

In human systems, adaptation to climate change is conceptualized as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, it is the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2019). Adaptation entails different dimensions and many other concepts which are equally defined below.

2.1.6. Ecosystem-based Adaptation (EbA)

The use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change (Campbell et al., 2009; cited in IPCC, 2019).

2.1.7. Evolutionary adaptation

The process whereby a species or population becomes better able to live in a changing environment, through the selection of heritable traits. Biologists usually distinguish evolutionary adaptation from acclimatisation, with the latter occurring within an organism's lifetime (IPCC, 2019).

2.1.8. Incremental adaptation

Adaptation that maintains the essence and integrity of a system or process at a given scale (Park et al., 2012). In some cases, incremental adaptation can accrue to result in transformational adaptation (Termeer et al., 2017; Tàbara et al., 2018). Incremental adaptations to change in climate are understood as extensions of actions and behaviours that already reduce the losses or enhance the benefits of natural variations in extreme weather/climate events (IPCC, 2019).

2.1.9. Transformational adaptation

This stands for adaptation that changes the fundamental attributes of a social and ecological system. It aims at anticipating climate change and its impacts; and adopting adaptation responses that will be required in the face of a global failure to mitigate the causes of anthropogenic climate change. The responses are characterised by system-wide change or changes across more than one system. They focus on the future and long-term change, and

question the effectiveness of existing systems, social injustices and power imbalances (IPCC, 2019).

2.1.10. Adaptation limits

The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions. Hard adaptation limit – No adaptive actions are possible to avoid intolerable risks. Soft adaptation limit – Options may exist but are currently not available to avoid intolerable risks through adaptive action (IPCC, 2019).

2.1.11. Adaptation options

The array of strategies and measures that are available and appropriate for addressing adaptation; they include a wide range of actions that can be categorised as structural, institutional, ecological or behavioural (IPCC, 2019).

2.1.12. Adaptive capacity

The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences (IPCC, 2014; IPCC, 2019).

2.1.13. Maladaptive actions (Maladaptation)

Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence (IPCC, 2019) of adaptation actions.

2.1.14. Mitigation of Climate Change

Mitigation of climate change is defined as any human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2012). In other words, it is the sum of strategies and policies that lower the concentration of greenhouse gases in the atmosphere either by reducing their emissions or by increasing their capture (Adhikari et al., 2011).

2.2. Literature Review

2.2.1. The System of Rice Intensification, Origin and Principles

The System of Rice Intensification was synthesised by Father Henri Laulanie in 1983, in Madagascar, as a result of two decades of experimenting various farmer practices and his own innovations (Laulanie, 1993; Stoop et al., 2002). He transplanted very young rice seedlings (15 days) with wide spacing (25*25 cm) in straight rows and columns for easy mechanised weeding and practiced intermittent irrigation to keep soil moisture instead of continuous flooding (Stoop et al., 2002; Gathorne-Hardy et al., 2013). He then observed outstanding results: well developed rooting, huge increases in tillering and grains number (Stoop et al., 2002). He therefore analysed his results in light of a previous study conducted by Katayama in 1951 (Veeramani et al., 2012). According to Stoop et al. (2002), rice plants achieve their full tillering and production potential when transplanted before entering their fourth phyllochron of growth and when grown under favourable soil, water and plant nutrient conditions.

Laulanie, in 1990, helped in creating an NGO (association Tefy Laina) with the aim to introduce the SRI in many communities around the country (Laulanie, 1993). The expansion work was later on joined by the Cornell International Institute for Food, Agriculture and Development (CIIFAD), in 1994 (Stoop et al., 2002).

The SRI is summarised around six major principles which are (1) transplanting of early age seedlings (eight to fifteen days old), (2) Single seedling per hill, (3) wide spacing transplanting, (4) early and regular weeding, (5) alternate wetting and drying and (6) application of organic fertiliser (Stoop et al., 2002; Uphoff, 2008; Reddy and Mortkori, 2013). Of these six principles, Laulanie insisted that the following are indispensable for the system to be called SRI: (1) alternate wetting and drying, (2) single plant per hill, (3) early age seedlings (eight to fifteen days) and (4) wider spacing (Laulanie, 1993). On the latter principle-wider spacing, he did not make unchangeable indications on the spacing but rather posted it as a function of the altitude, which in turn dictates temperature and daylength. For the purpose of this study, a farmer is considered as a full adopter if he adopts these six principles. Anything less is called partial adoption. With regards to wide spacing, anything equals to or beyond 20*20 cm is considered so, and with regards to age,

anything between eight to fifteen days is considered early age transplanting since those were parts of the recommendations during SRI introduction in the two areas.

2.2.2. Introduction and spreading of SRI in West Africa and Mali

On the course of its expansion globally (Katambara et al., 2013; Noltze et al., 2013) upon its successes, SRI has been introduced in West Africa in recent years (Uphoff, 2016). According to Styger et al. (2011), the SRI was first tested in Mali in 2007, through 2009. The test program was implemented by an NGO named Africare which was intervening in Goundam and Diré circles. The NGO helped the communities to establish village-based small-scale irrigation schemes (*Périmètre Irrigué Villageois*, PIV) of 30-35 ha each and irrigated by motor pumps to tackle food insecurity experienced by the local communities (Styger et al., 2011). On these PIV, the yields were higher than that of deep-water rice production system that farmers were practicing (4.9 t/ha compared to 750 kg/ha) but the land area allocated to households were still small (1/3 ha per household) (Styger et al., 2011). Therefore, it was necessary to find means to further increase the yields. It was in that context and perspective that the SRI was tested in Goundam and Diré circles. In 2007, the NGO Africare first tested the SRI with one farmer in the Douegoussou village, in Goundam circle; the results were outstanding (9 t/ha of paddy compared to 6.7 t/ha in the control plot), farmers in the area therefore expressed great interest in larger scale testing of the SRI (Africare Mali, 2008).

Based on these first results and farmers' interest, the Better U Foundation of Los Angeles, California, made a grant to Africare for a larger project: to assess the performance of SRI in 12 villages during the 2008–2009 growing season in the circles of Goundam and Diré. The main objectives were to: (a) adapt SRI principles to the local rice cropping system conditions, and (b) compare SRI practices with farmer practices in 12 sites within two administrative circles of the Timbuktu region.

The SRI continued its expansion and involved different partners and NGOs. In 2015, the German Society for International Cooperation (GIZ) through its Green Innovation Centre (CIV) engaged in the promotion of the SRI. In 2018, CIV simultaneously introduced the SRI in both Baguinéda and Sélingué irrigated schemes. They trained some farmers and extension service agents on the application of the six SRI principles and the Deep Urea

Placement technique. The trained farmers were also provided both required chemical and industrial organic fertilisers for the test plots. The used diffusion method was Farmer Field School (FFS) technique and the test program initially lasted for three years.

However, from the introduction till this date, no study was conducted to objectively evaluate the adoption and evolution of the SRI in these two areas. The study aims to deliver on this.

2.2.3. SRI attributes and challenges vs conventional practice

First of all, what we mean by conventional practice is worth clarifying. The conventional practice in this context of rice production refers to a method of rice plant, soil and water management in the production system. (1) It involves continuous flooding i.e. supplying the rice field with much water (generally 15 to 30 cm) during the whole cycle of the production, from transplanting to harvest. This practice is to some farmers a way to control non-aquatic nature weeds in the rice field (Ismail et al., 2012). (2) The transplanted seedlings are 21 days old or more and transplanted two or more seedlings per hole (Katambara et al., 2013) with narrow and irregular spacing (generally less than 15 cm). Finally, (3) under this method, less weeding activity occur due to water reducing the weed population.

The system of rice intensification is known to have several benefits over conventional rice production practices. Indeed, many studies (Stoop et al., 2002; Satyanarayana et al., 2007; Zhao et al., 2009; Baskar et al., 2012; Uphoff et al., 2012; Choi et al., 2013; Katambara et al., 2013) conducted in Africa, southern and eastern Asia argue that the SRI technology increases yield (can double) and save water. It can allow to save up to 64% of irrigation water (Kombe, 2012). In addition to yield increase and water saving, Katambara et al. (2013) supported that the SRI requires less farm inputs compared to conventional practice. One hectare requires 10 kg of seeds under SRI and 60 to 80 kg under most conventional practices. Katambara et al. (2013) also supports that using less seeds and transplanting at wider space reduces the time and work dedicated to the transplanting activity and reducing the costs since less inputs are used. The same author indicates that under SRI the plant stems are healthier and robust, making them more resistant to pests and diseases, high

winds and reduce at the same time the water runoff from the fields with a well-developed root system and important tillering.

However, the SRI is not clean from challenges. The alternate wetting and drying practice required in the SRI system suggested that farmers be able to supply and drain their fields at will, which implies that there should be no seepage from one field to another (Katambara et al., 2013), which in practice is rare in most irrigated schemes. It becomes more complicated when some farmers practice continuous flooding while others practice SRI and when farming activities are not synchronised. In addition, the alternate wetting and drying allows more weeds to grow (Katambara et al., 2013) and therefore requires more weeding work. In addition, Gathorne-Hardy et al. (2013) indicated that the control of weeds using mechanical equipment which disturbs the soil surface is highly recommended to achieve the active soil aeration that better supports the growth of roots and the aerobic soil biota. However, this can be compromising in areas where mechanical weeding is not developed or the weeder not accessible let alone where access to labour is a challenge.

Moreover, the required water amount to irrigate the field being low under SRI (keeping the soil moist) (Laulanie, 1993; Stoop et al., 2002), it imposes that the field be well-levelled enough to allow shallow irrigation water to reach the field end from the entry point. This required levelling might practically be difficult for most farmers in developing countries due to low level of equipment.

In sum, while it is agreed that the advantages of the SRI practice overweigh its challenges in many aspects, it should also be noted that its implementation requires some criteria to be met and some level of equipment.

2.2.4. Technology adoption in agriculture

First of all, it should be noted that in the context of this study technology and innovation have the same meaning.

The adoption of a technology has been defined by Rogers (2003) as the decision to make full use of an innovation. That definition would be full and complete if the technology referred to is a single action, practice, or tool like improved seeds adoption for example, in which case the farmer simply decides to use it or not. However, in most cases technologies

come as packages of actions. The SRI is one of such cases. Indeed, it is a sum of actions that can be adopted alone or separately. This brings out the concept of partial adoption, which refers to the adoption of one or more principles of a technology without adopting the others.

Technology adoption is a subject of great interest in agricultural research (Feder et al., 1985; German et al., 2006; Pannell et al., 2006; Knowler and Bradshaw, 2007; Alcon et al., 2014; Hailu et al., 2014). The aim of innovating and developing new technologies is that they be adopted at the end by the farmers in order to ameliorate their livelihood, alleviate their workload, increase their yield and income (Cafer and Rikoon, 2018). Sometimes, the low rate of adoption imposes that we question the technology itself, the adoption process, the environment and the enabling and/or disabling factors.

Poornima (2019) states that farmers will adopt a practice or a combination of practices that can provide maximum utility to them. Subject to various constraints and in order to maximize the utility, a farmer will compare alternative practices and combinations. This implies that the adoption of a new technology is not a straight forward process. Indeed, the adoption process seems complex and technology-specific. Theis et al. (2018) states that "technologies and innovations have traditionally been delivered to smallholder farmers through a technology push of recommended agricultural practices and then have been expected to diffuse over time across social systems". Clarke et al. (2018) supports that adoption can either be a slow process or occur suddenly depending on circumstances.

2.2.5. Technology adoption factors / SRI adoption determinants

The ultimate aim of innovation and development of new technologies is their adoption by farmers to solve their daily problems (Cafer and Rikoon, 2018). The surprisingly slow process or low rate of adoption (Theis et al., 2018) justifies the great interest of researchers and the many studies (Griliches, 1957; Kebede, 1992; Marra et al., 2003; Pattanayak et al., 2003; Leeuwis and Van den Ban, 2004; Hogset, 2005; Ayele et al., 2012; Gilles et al., 2013; Kebede and Tadesse, 2015; Clarke et al., 2016; Alexander and Larson, 2016; Alexander et al., 2018; Philp et al., 2019; Alexander et al., 2020; Moore et al., 2024) that have been conducted on the subject to either understand the process or identify the factors determining technologies adoption, including SRI.

In this regard, Marra et al. (2003) indicates that adoption decisions at individual level are dependent on the characteristics of the potential adopters, including their adoption behaviours, the communications and learning involved in various stages of innovation decisions processes and the subsequent perceptions that surround the attributes of the innovation. In other words, this means that the adoption of a technology is determined by the nature of the farmer, the nature of the technology and the components of the diffusion environment (Sattler and Nagel, 2010). This justify why some success recording technologies in one location could be a failure in a different location, since the background of the beneficiaries and the environments might differ. Therefore, anytime there is new technology introduction in a given place, adoption evaluation studies must follow to help understand the level, processes and identify the determining factors in order to develop strategies that will promote the technology if necessary, or discard it if not.

Poornima (2017) investigated the adoption of SRI under information constraints in India. He used questionnaires to survey SRI adopters and non-adopters and analysed how effective information access determines the adoption level and depth along with gender, age, education level, household size, labour availability, owned assets, irrigation facility and other factors. The results showed that SRI adoption is clearly not straight forward and the adoption of each principle is conditioned to the fulfilment of a set of criteria to be met. They found that FBO membership, level of equipment, irrigation facility and labour availability have positive impact on adoption. Moreover, the study revealed that the age of the household head negatively influences SRI adoption intensity i.e. the older the household head the less likely the adoption.

Moore et al. (2024) conducted a study to analyse the SRI adoption decisions dynamics in Madagascar and the differences between adopters and nonadopters. They surveyed 328 rice farming households in southeastern Madagascar. The results indicated that despite the willingness of farmers to adopt the SRI, the actual rates of adoption were low while dis-adoption were high. Only 21.6 % of farmers having declared their intention to adopt SRI in year n-1 could actually conduct its trials in year n. During the study, farmers also indicated lack of suitable quality seeds, limited labour, time and resources constraints as reasons for not adopting SRI. In addition, they used a model that indicated that participation to

trainings and household assets are significant predictors of SRI adoption. This implies that these factors could be important for SRI adoption.

Kabir et al. (2024) studies the determinants of SRI adoption in Kano State, Nigeria. They used multistage sampling techniques to select and interview 286 farmers with a structured questionnaire, and they used descriptive and inferential statistics (logistic regression) to analyse the data. The results indicated that the gender, education level, FBO membership, marital status and organic fertilizer were determinant of SRI adoption. The study also revealed that the major constraints to SRI adoption included limited household size, low education, limited input access, inadequate training, flooding, pests and limited market access.

Mkubya et al. (2023) studied the socio-economic factors influencing the adoption of SRI among smallholder rice irrigation farmers in Morogoro Region, in Tanzania. They used questionnaire and key informant technique to collect data from 384 farmers selected through multistage sampling, and used logistic regression model to analyse the data. Results showed that access to extension service has positive impact on SRI adoption and that the major constraint was limited access to labour, which increases under SRI versus conventional methods.

In the same country, Mhango (2024) studied the factors influencing the adoption of SRI among smallholder farmers in Mvomero District. He used a simple random technique to sample 299 respondents and purposeful random technique to interview key informants. He analysed the data using Two-limit Tobit model and found that Marital status, land ownership, availability of paddy markets, knowledge, age and education level had significant influence on adoption of SRI.

Pattanayak et al. (2003) evaluated statistical models of the adoption of technologies and found that adoption variables could be classified into five broad categories: household preferences, biophysical factors, resource endowments, economic incentives, and perceived risk and uncertainty. Specifically, he found that the factors more likely to be correlated with adoption decisions included: soil quality, extension and training, tenure, assets, savings and credit. Jones (2005) found that adoption decisions were influenced by several

variables: education, extension, membership of Farmer-Based Organisation (FBO), health, cash cropping and soil quality. Meanwhile, variables that statistically correlated with decisions to dis-adopt included: education, experience, expected price and type of soil. Nonvide (2021) found that education, extension services, FBO membership, access to credit and media, and use of mobile phones are key factors determining technology adoption. Feder et al. (1985) conduced a review of empirical and theoretical studies on adoption and found that the key explanatory factors influencing adoption in these studies were: farm size, risk and uncertainty, human capital, labour availability, credit constraints, tenure, supply constraints, and aggregate adoption over time.

The results from these multiple studies highlight three major elements that contain the adoption factors, (1) the farmer and its attributes, (2) the technology itself and (3) the environment. The environment includes all that which is not related to the previous two elements. It can be the institutional arrangement and management, communication, land ownership, tenure and biophysical characteristics and more. The technology itself, might be simple and easy-going or complex, require less or more skills and or criteria to be implemented. The farmers' education level and skills, openness to new ideas, equipment ownership, organisation membership and more other might be determinant in the adoption decision and process. Therefore, in this study we tried to capture the influence of most of these elements on SRI adoption level and processes (see methodology section).

2.2.6. SRI adoption evaluation approaches

Following the introduction of a new technology, one of the most important and logical things to do is to investigate how it unfolds. This means to enquire how farmers accept or reject partially or fully the introduced technology, how it is modified based on their experience and local context.

Poornima (2019) states that farmers will adopt a practice or a combination of practices that can provide maximum utility to them; subject to various constraints and in order to maximize the utility, a farmer will compare alternative practices and combinations. This implies that the adoption of new technologies is not a straight forward process. Therefore, such investigations produce information and knowledge necessary (1) to reinforce, improve

and or restructure the technology for better adoption and result or (2) to realise that the technology is not feasible in the area and abandon or exchange it.

Since its establishment, the SRI has been introduced in many places around the world (Katambara et al., 2013; Noltze et al., 2013). Therefore, studies have been conducted in several of those places for its evaluation. These studies have adopted different approaches and found different results and focused on different aspects of the adoption. Indeed, Balamurugan and Rajasekaran (2019) conducted a study on constraints experienced by the farmers in the adoption of SRI technologies in Krishnagiri district, India. They used questionnaires to interview a total number of 120 respondents, identified from 10 selected villages using proportionate random sampling method. The results showed that among the bio-physical constraints, the most important expressed by vast majority of the respondents were inundation due to monsoon and floods (88.33 %), difficulty in draining the water during rainy season (72.50 %), improper maintenance of channels (71.66 %), and non-availability (39.16%) and ineffectiveness of *cono weeder* (manually operated mechanical weeder) due to unsuitable soil conditions. In addition to bio-physical constraints, the study reported that the major socio-economic and psychological constraints were non-availability of skilled labour (82.50 %), lack of confidence in the new technology (80.00 %), and high cost of labour (79.16 %), difficulty in transplanting young seedlings (75.00 %), difficulty in the adoption of row and line method of planting (61.67 %), non-availability of credit (38.33 %) and lack of subsidy for inputs (37.50 %).

Poornima (2019) investigated the adoption and the impact of system of rice intensification on rice yields and household income in six districts from three states in India. Mainly, the study focussed on determining the adoption factors based on econometric model. The multistage sampling technique was used to select and interview 386 household farmers (SRI-practicing and non-practicing farmers) using structured questionnaires. The author used the multinomial endogenous treatment effects model, and consider the adoption of SRI as a choice over five combinations comprising three major principles of soil management, plant management and water management. Farmers were classified into five mutually exclusive groups which were nonadopters (group 1), plant management (group 2), plant management plus water management (group 3), plant management plus soil

management (group 4), plant management plus soil management plus water management (group 5). He found that 38 farmers followed only the practices of plant management, 19 farmers followed both the practices of plant and water management, 47 farmers followed both plant and soil management practices, and 89 farmers followed plant, water and soil management practices (Poornima, 2019).

Moreover, Moore et al. (2024) used questionnaire to survey 328 rice farming households in southeastern Madagascar, in order to analyse the SRI adoption decisions dynamics in Madagascar and the differences between adopters and nonadopters.

In these studies, we can realise that most of the authors conducted evaluation studies using field survey approach. However, in our study, in addition to field survey in the locations, we had intended to conduct a field experiment in Sélingué irrigated scheme in order to directly experience the challenges related to SRI implementation in the area.

CHAPTER THREE

3.0. RESEARCH METHODOLOGY

This chapter presents the study area, mentions the reasons that justifies their choice. It also describes the data required to answer the different research questions and the methods used for their collection. Finally, it describes the analyses that were performed to answer each research question of the thesis.

3.1. Study area

3.1.1. Choice of the study sites

Sélingué (11°38′18″ N, 8°13′47″ W) and Baguinéda (12°37'00" N et 7°47'00" W) irrigation schemes are the two research sites. The choice of the two sites is justified by the following reasons. The SRI was introduced in both Sélingué and Baguinéda simultaneously as part of the same project, in 2018, and with the same packages. Twenty farmers were selected in each location to participate to the training sessions on SRI principles. Among the participants, six farmers were selected to receive the trials on their fields in each location. In addition to these trainings, the selected farmers were given both required chemical and industrial organic fertilisers (Organova and Fertinova) for the land allocated to the trial. The Farmer School Approach (FSA) was used, each trial site was open to all farmers for visits and observation of the practices. The two locations therefore have similar experience related to SRI introduction. However, the two locations have different context on some other aspects. Sélingué is a rural area while Baguinéda is a peri-urban area. In addition, Sélingué is in the North-Guinean zone while Baguinéda is located the North Sudanian zone. The aim is therefore to find out how the SRI evolves in the two different contexts after its introduction through a comparative case study. Furthermore, though they have the same water source, the Niger river, Baguinéda is downstream and Sélingué is upstream, so we would also like to capture whether their different locations and biophysical characteristics also affect the adoption process.

3.1.2. Climate

In general, climate in Mali is characterized by erratic rainfall, high evapotranspiration and higher temperature values, with a maximum of 51 °C, a minimum of 10 °C and a mean of

28 °C (MES, 2008). Since 1960, an annual increase of 0.7 °C in average temperature has been noticed (MES, 2008). In the 1950s, the annual precipitation used to vary within the range 500 and 1500 mm but in the course of the last 15-20 years the maximum has not been beyond 1300 mm (Bodegom and Satijn, 2015). Climate is also characterized by frequent droughts and annual rainfall variability (Bodegom and Satijn, 2015).

Mali has four agroecological zones (Figure 3.1), the Sahara zone in the northern area with an annual rainfall less than or equal to 200 mm, the Sahel and Soudan zones in the centre with annual rainfalls ranging from 200 to 800 mm and 800 to 1000 mm respectively, and the Sudano-guinean (North Guinea) zone in the southern part of the country with an annual rainfall of more than 1000 mm (LABOSEP, 2000; MES, 2008). Across the Sahel and the Sudan zones is located the Inner Delta of the Niger River, where most of the irrigated rice production of the country occurs.

This study was conducted in Sélingué and Baguinéda (Figure 3.1) irrigated schemes and surrounding farming villages, located in the region of Bougouni (Sélingué) and the region of Koulikoro (Baguinéda), respectively in the Sudano-guinean (North Guinea) and Sudan zones of Mali.

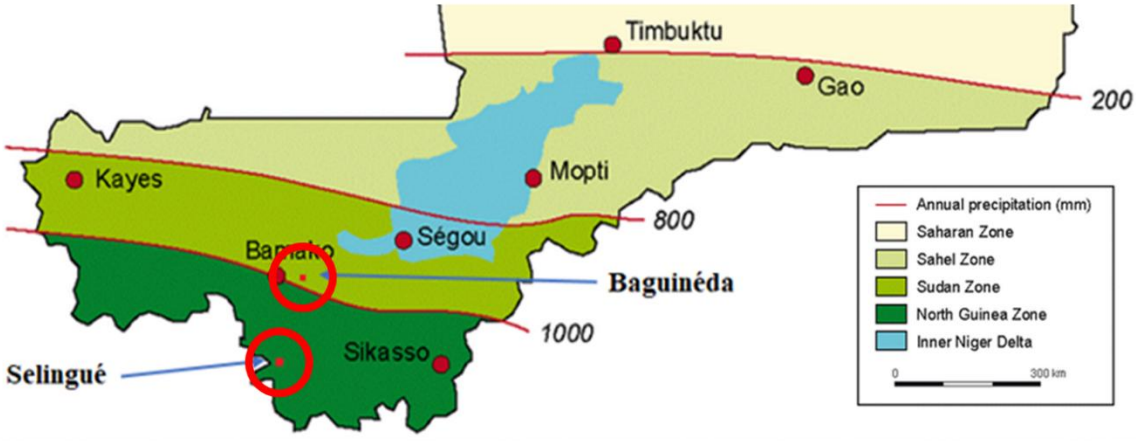


Figure 3.1: Study area and agroecological zones in Mali.

Source: Adapted from LABOSEP, 2000

3.1.3. Economic activities

The economic activities in Sélingué are structured around agriculture (rice production mainly), fishing and artisanal gold mining-developing in recent years. The construction of the dam and the irrigated scheme boosted several small businesses around rice production.

In Baguinéda, which is closer to Bamako, in addition to agriculture as main activity of most of the population, the influence of the big city has settled. This brings many people in small businesses and spread land speculations.

3.1.4. Organisation of the labour in Sélingué and Baguinéda

In the two locations, the families are of extended type and the production activities rely on family members in the first place. In other words, the labour for the agricultural activities in the two locations is mainly from within the families. Some works are primarily reserved for men while some others are for women. Land and nursery preparation, fertilisers and herbicides/pesticides applications, irrigation and drainage are mainly done by men while transplanting and weeding are mainly done by women. Both men and women work along in the harvest. Some works requiring motored cultivator (labour, levelling and puddling) or threshing machine (for threshing) are either done through paid service or with animal-pulled ploughs (done by men), or by women for the threshing. In addition to family members or in its absence, external workers are engaged for the works requiring manpower. This makes it clear that both labour endowment or availability and financial means are critical for the rice production activities. However, as for Sélingué, in recent years artisanal gold mining has been booming across the territories and that is leading to a changing a situation. It is indeed considerably draining in the youth that normally constitute the labour forces in rice fields.

3.1.5. Presentation of Sélingué and description of the irrigated scheme

Sélingué is the name of one of the villages that were displaced to construct the dam. This village is actually located on the left bank of the Sankarani river, a tributary of the Niger river. Indeed, several villages with a total of nine thousand people were displaced to construct the dam. The farms in the irrigated scheme are mainly attributed to the farmers from these villages. Presently, seventeen villages accommodate farmers exploiting the

irrigated scheme. The population is mainly composed of *Malinkes* (autochthons), *Dogon* and *Bozo,* mainly immigrants. The *Dogon* people immigration was encouraged by the government, back then, due to scarcity of land resources in their original place coupled with the fact that the irrigated scheme was not fully exploited by the beneficiaries in its first years. The *Bozo* community are fishers, if some settled before the dam was constructed, both their community and activity were expanded due to the water holding capacity of the dam. In addition, the development programs of the management institutions always include fishery development components. The commonly spoken language is the *Malinké*. However, both the *Bozo* and the *Dogon* people speak their own languages within their communities.

The Sélingué hydroelectric dam named "*Barrage de Sélingué*" and the irrigated scheme-watered by the same dam were constructed from 1977 to1981. The exploitation started the next year, in 1982, after the inauguration. With the double purpose of hydroelectric power production and irrigation of rice fields, the dam has a water stockage capacity of two billion cubic meters. In addition to electricity production and the irrigation of the scheme, the dam has also a purpose of maintaining water levels high for its usage downstream the river, including the Baguinéda irrigated scheme.

The irrigated scheme is located at 140 km from Bamako, capital city. It covers an overall area of 1 350 ha in total, including roads, drainage and irrigation canals. The total net area dedicated to rice production in the Sélingué irrigated scheme is 872 ha. Hundred and twenty-three hectares (123 ha) are dedicated to the cultivation of maize, sweet potato, banana and some vegetables crops. Rice is produced on both seasons, and the total number of producers in the scheme is 2051 (1835 men and 216 women), with women representing 10.5 %. The average plot size per producer is 0.43 ha.

Structure and protection infrastructure of the scheme

The irrigated scheme is divided into fourteen sectors, numbered from 11 to 24. Each sector can be considered as an autonomous scheme, water-supplied by a secondary canal through a secondary inlet (on the main canal), and drained by a secondary culvert which drains into the main culvert of the scheme. Each sector is divided into elementary compartments with an average gross surface area of 6 ha and an average net surface area of 5.11 ha, after

deduction of the areas occupied by the roads, irrigation and drainage canals. With its 872 ha of net area dedicated to rice, there are 170 compartments. The compartments are grouped in fours (4) to form a sub-sector, water-supplied by a tertiary canal through a tertiary inlet (on the secondary canal which borders the sector to the south), and drained by a tertiary culvert which drains into the secondary culvert bordering the northern sector.

With regards to the protection of the scheme, the scheme is protected in the south by the platform of the hydroelectric dam and on the west, between the scheme and the Sankarani river bed, by an elevated dike of 13,545 m long with a width of 4.50 m. This is necessary because of the risk of the plain being submerged by flooding from the river. At the downstream end of the scheme (lowest point), where the main culvert C1 which collects excess water from the scheme, opens out, the dyke is equipped with a structure for draining water into the river. This structure consists of a quadruple gravel drainage pit, equipped with non-return drainage valves, and a drainage pumping station, equipped with three electric generators, whose role is to ensure the drainage of the scheme when the water level of the river, in flood, is higher than that of the plain and when, consequently, drainage by gravity has become impossible. In the east of the scheme, parallel to the main irrigation canal P1, a channel was created to drain run-off water from the plateaux till the river.

Irrigation network

The scheme is equipped with one water intake (with a capacity of 3 cubic meter per second). This intake provides water to the main irrigation canal sectioned in two, therefore considered as two irrigation canals, P1 and P2. The total length of the two main irrigation canals is 10.7 km, 6,522 m for P1 and 4,201 m for P2. To the main irrigation canals are connected thirteen secondary irrigation canals, it could be counted fourteen if we consider the fact that P2 plays the role of secondary irrigation canal by directly receiving tertiary irrigation canals on its section crossing longitudinally the scheme. The total length of the thirteen secondary irrigation canals is 11.8 km. Each secondary irrigation channel irrigates through the tertiary irrigation canals a separate and independent sector. In other words, a sector is the sum of the compartments irrigated by the same secondary irrigation canal. To the secondary irrigation canals and P2 for its concerned section, are connected 50 tertiary irrigation canals with a total length of 27.99 km. Each tertiary irrigation canal irrigates a set of four compartments, called a sub-sector. The total length of three levels of irrigation

canals is 50.5 km. The tertiary irrigation canals provide water to gullies in each compartment, and plots are irrigated from the gullies. The net area per rice production compartment being 5.11 ha, we can deduct that there are 611 m of irrigation gullies per compartment, and similar for drainage.

The system of irrigation on the scheme is gravitational.

Drainage network

The scheme is equipped with one outlet, on its lowest point. This structure consists of a quadruple gravel drainage pit, equipped with non-return drainage valves, and a drainage pumping station, equipped with three electric generators, whose role is to ensure the drainage of the scheme when the water level of the river, in flood, is higher than that of the plain and when, consequently, drainage by gravity has become impossible.

There are drainage gullies in the comportments that drain water into the tertiary culverts, which drain into the secondary culvert to finally end in the main culvert, before returning into the river. Similar to irrigation gullies, there are on average 611 m of drainage gullies per compartment. Like tertiary irrigation canals, there are 50 tertiary culverts, with a total length of 23 865 m. There are fourteen secondary culverts, numbered from C11 to C24, with a total length of 14 100 m. The main culvert is 10 285 m long. The total length of the drainage culverts (tertiary, secondary and main) is 48.25 km.

Roads network

The scheme is equipped with some primary, secondary and tertiary roads. The primary or main roads, along the main irrigation and drainage canals, have a width of 6 meters and a total length of 22 050 m. The secondary roads, along the secondary irrigation canal, have a width of 4.5 m and a total length of 13 700 m. The tertiary roads, or compartments interconnecting roads, have a width of 3 m and a total length of 26 750 m. In sum, the total length of all the roads is 62.5 km.

Each sector is crossed along its longitudinal axis by an interconnecting route that provides access to each compartment at all times of the year.

3.1.6. Presentation of Baguinéda and description of the irrigated scheme

The Baguinéda irrigated scheme covers an area of twenty-two villages. These villages are located along the irrigated scheme, going from Bamako to the "Faya Forest". Baguinéda-camp, hosts the local authorities of the constituency which counts thirty-two villages. This town, which currently accommodates the irrigated scheme management directorate, was originally a territory of Baguinéda-village, reserved for the settlement of the construction workers of the scheme, the different projects staffs and their families eventually. That is why it is called Baguinéda-Camp, the camp of Baguinéda. In addition to the construction workers and projects staffs, the town later on received the personnel of the different management institutions that successively managed the irrigated scheme. The constituency was later on created in 1996, with Baguinéda as chief town. The various ethnic groups of the constituency include *Bambara* (the dominant ethnic group), *Fulani*, *Bobo*, *Sénoufo*, *Minianka* and a few *Bozo* from the region of Mopti. The commonly spoken language is *Bambara* (PROMISAM-USAID Mali, 2008). In the territories, the families are of extended type and the production activities rely on family members in the first place.

The irrigated scheme of Baguinéda, around 20 km in length and a width of around 2.5km, initially belonged to the Niger Office "*Office du Niger*", which produced cotton and rice from 1930 to 1959, from an irrigation infrastructure that was built from 1925 to 1929. Upon the country's independence, in 1960, the scheme was almost abandoned by the Niger Office for inner lands in the Region of Segou, more productive. The average rice yield was back then 0.3 tons per hectare due to degraded irrigation network and overwhelming weeds. From the independence to recent years, the irrigated scheme has received several construction, rehabilitation and expansion programs to reach its current state.

The irrigated scheme is located at 30 km from Bamako, capital city. It covers an overall area of 3,000 ha in total, including roads, drainage and irrigation canals. The total net area for cultivation is 2,556 ha, with 2,428 ha dedicated to rice production and 128 ha for other crops. The total number of producers is 3,389, with 3,252 men and 137 women-less than one percent. The average plot size per rice producer is 0.72 ha. In addition to rice, which is mostly produced during the rainy season, the other seasonal crops are maize, sorghum, beans, groundnut and millet. Despite being mainly produced during the rainy season, some of these crops are produced in smaller extent during the off-season, except sorghum and

millet, which are not produced at all during the off-season. The main off-season legumes are aubergine, cabbage, cucumber, courgette, okra, African eggplant, onion, sweet potato, pepper, tomato and Irish potato.

Structure and protection infrastructure of the Scheme

While the Sélingué irrigated scheme is subdivided following the irrigation canals, the Baguinéda irrigated scheme is subdivided according to villages and groups of villages. However, to make the parallel with Sélingué, we decided to refer to the irrigation network for better and easy understanding. There are four sectors which are Sector I (Kobala-Coura), Sector II (Baguinéda-Camp), Sector III (Sébéla) and Sector IV (Tanima). Each sector is divided into sub-sectors following the secondary canals and into blocks following the tertiary canals. Sector I has seventeen subsectors, twelve, six and seventeen sub-sectors for Sector II, III and IV respectively. The average block size is 6.76 ha.

With regards to the protection of the scheme, there are 25 km of protective dyke.

Irrigation network

The irrigated scheme is water-supplied by the Niger river from the dam called "*Barrage des aigrettes*" and at its end, the drainage water also returns to the same river. The water intake has a maximum capacity of 12.5 cubic meter per second. This dam "*Barrage des aigrettes*" also supplies water to the Sotuba hydro-electric power central. The system of irrigation on the scheme is gravitational.

In each sector, the secondary canals are connected to the primary one. There are fifty-two secondary irrigation canals. These fifty-two secondary canals are split into seventeen secondary canals for sector I, twelve for sector II, six for sector III and seventeen for sector IV. The secondary canals supply water to the tertiary ones which in turn irrigate the fields through the gutters. The main irrigation canal has a total length of 37 km, going from Bamako to the exit into the Niger river, and the fifty-two secondary irrigation canals and the four hundred and forty-two tertiary irrigation canals measure 56 km and 144 km, respectively (Héritier, 2017). There are 2 331 gutters in total and seven regulators, regulating water at some sections on the main irrigation canal.

Drainage network

Similar to the irrigation network, there are primary, secondary and tertiary drainage culverts, in addition to drainage gullies at blocks' level. The drainage gullies in the blocks drain water into the tertiary culverts, which drain into the secondary culverts to finally end in the main culvert, before returning into the river. The main drainage culverts measure 35 km, and the secondary and tertiary culverts measure 59 and 174 km, respectively.

Roads network

To ensure good traffic flow across the scheme, a network of carriageways has been built along all the irrigation canals (from the main canal to the tertiary ones), secondary and tertiary culverts. In total, there are 47 km of main roads, 56 and 144 km of secondary of tertiary roads.

3.1.7. Management of the irrigated schemes

Sélingué

The management of the irrigated scheme is jointly assured by the *Office de Développement Rural de Sélingué* (ODRS) created in 1996 (by the law "Loi n°96-042/AN-RM du 07 *août* 1996"), the Government and the producers. Two management institutions preceded ODRS, the authority for the construction "*Autorité d'Aménagément de Sélingué*, 1977-1982", in charge of the resettlements and the construction activities, and the "*Office pour l'Exploitation des Ressources Hydrauliques du Haut Niger* (OERHN), 1982-1996", with the double purpose of electricity production and the rural development of the whole area including the management of the irrigated scheme. In 1996, the two missions were split, the dam and the electricity production were assigned to the national company of energies "*Energie du Mali*, EDM-SA" and the rural development and the management of the irrigated scheme to ODRS, created for the very purpose.

For the current management, it is jointly assured by the *Office de Développement Rural de Selingué* (ODRS), the Government and the producers. The three parties, ODRS-Government-Producers are bound by a contract document named "*Contrat-Plan*". This document which is renewed every three years stipulates the roles and responsibilities of each party for the operationalisation, extension and maintenance of the irrigated scheme.

The Government is in charge of extending and maintaining the primary roads, irrigation and drainage canals, and the outlet infrastructure and equipment. The secondary roads, irrigation and drainage canals are maintained by ODRS while producers assure the maintenance of the tertiary ones and the gullies in their compartments. Besides, producers pay water usage fees to ODRS, and ODRS among other activities assures the assistance, training, input access facilitation and advisory service to producers for their production activities on and beyond the irrigated scheme. ODRS also elaborates the production calendar, controls and supervises its implementation.

Baguinéda

As similar to ODRS, the management of the Baguinéda irrigated scheme is also jointly assured by the *Office du Périmètre Irrigué de Baguinéda* (OPIB), the Government and the producers. They are also bound by the "*Contrat-Plan*" (renewed every three years) which stipulates that the Government is in charge of extending and maintaining the primary roads, irrigation and drainage canals. The secondary roads, irrigation and drainage canals are maintained by OPIB while producers assure the maintenance of the tertiary ones. Similarly, producers pay water usage fees to OPIB, and OPIB assures the assistance, training, input access facilitation and advisory to producers for their production activities on and beyond the irrigated scheme, elaborates the production calendar, controls and supervises its implementation.

In both locations farmers are associated to the management through joint committees "*les comités paritaires*" in charge of land and maintenance funds management. These committees, presided by ODRS and OPIB are composed of sixteen members, eight representatives of producers and eight representatives of ODRS for Sélingué and OPIB for Baguinéda. The committees should be renewed every three years. These committees deliver on plots attribution, reattribution and retrieval. They also deliver on the use of funds intended for the reparation and maintenance of relevant infrastructures. These funds are constituted of water usage fees paid by all producers. The committees are also responsible for coaching farmers to proceed to the maintenance of tertiary canals and decide of sanctions in case of no execution.

In addition to the "*Contrat-Plan*" and the joint committees, it is instituted that all farmers sign and respect operating conditions documents "*Cahier des charges*" with ODRS/OPIB. These documents legally bind ODRS/OPIB and farmers. They engage through this document to pay water usage fees, permanently cultivated their fields, clean and maintain the tertiary canals. The document also highlight that the plots should not be borrowed, rented, sold or inherited.

3.2. Data

In accordance with the research questions, some data required to answer most of these questions could only be collected from farmers directly. Therefore, we used questionnaires to collect the required data from farmers. In addition to the questionnaires, we conducted Focus Group Discussions (FGD) with farmers and women transplanters in both locations, field observations, and interviews with staff members including field technicians to collect, check and validate the data before analysis.

Specifically, the first question on the adoption level of SRI principles since its introduction required data from both the technical management of the irrigation scheme (for triangulation) and the farmers themselves. The technical management keeps record (though not consistent) of the number of SRI practicing farmers-those applying some observable principles of SRI like square (row and line) transplanting. However, information on the age at transplanting, fertilisation, irrigation and weeding practices, could only be provided by the farmers themselves, therefore, collected from them. It is worth noting that technical management staffs in the two locations did not put in place follow-up mechanisms with regards to the application of SRI principles. Therefore, they stated that they consider a farmer as adopter if he/she applies at least one principle, generally the most visually observable like square transplanting, and that, with less consideration for the spacing.

The second question on the factors determining the adoption or non-adoption of SRI at farmers' level pertains to farmers' socio-economic status and the overall environment including biophysical and institutional. This also required data from farmers and all stakeholders and the way they interact with one another.

The third question on the technical, technological and managerial conditions favouring or hindering the application of SRI principles in the study areas required data from literature on the SRI technical and technological requirements. It also requires data on the conditions and constraints mentioned by farmers to favour or hinder the adoption of SRI principles in addition to the challenges we observed while conducting the field experiment. Finally, the roles of the governance and institutional framework-managerial conditions in the adoption of SRI required deductive and inferential analyses of the data collected for the three previous questions, the literature, and governing documents of the irrigated schemes.

The questionnaires were designed to capture these specific elements.

Moreover, to better understand and interpret the data collected from farmers, we drew from the field experiment conducted in Sélingué irrigation scheme in 2022.

3.2.1. Questionnaire

The questionnaire (Annex I) was designed in eight sections. The first section was on the characterisation of the household including names, addresses, age, gender, instruction level, household and land sizes, engagement of extra workers, produced crops and possessed equipment. The second section addressed the main activities and source of income of farmers. The third section addressed the membership of farmer-based organisations and access, extension services and involvement with partners. The fourth section was on the rice production knowledge in general, practices and dynamics. The fifth section addressed specific knowledge on SRI, its advantages, constraints and adoption strategies. The sixth section addressed the use, access and constraints related to inputs. The seventh section addressed the yield difference under SRI and conventional practices. The last section aimed to capture the requirements farmers believe should be met before they could apply all the SRI principles and to know their last words.

The questionnaires were tested and refined in order to remove ambiguous questions and be sure of a timely administration.

These elements were included in several studies on technology adoption in agriculture in general (Feder et al., 1985; Jones, 2005; Pannell et al., 2006; Knowler and Bradshaw, 2007;

Sattler et al., 2010; Cafer et al., 2018), and on SRI adoption evaluation in particular (Poornima, 2017; Poornima, 2019; Balamurugan and Rajasekaran, 2019).

With regards to the focus group discussions with farmers, group of women transplanters and interviews with staff members and field technicians were covered. The discussed topics are indicated in Annex II, III and IV.

3.2.2. Sampling

in Sélingué as well as in Baguinéda, the absence of consistent record of the list of adopters and nonadopters was observed. Given this context, the purposive sampling technique was used. We asked the management staff to consult their field technician on ground and farmers organisations leaders in the villages and provide us a list of sixty farmers (thirty adopters and thirty nonadopters based on their best knowledge). That summed up to a list of hundred and twenty farmers to be interviewed in the two locations. The selected farmers were then identified and interviewed through the facilitation of the field technicians and farmers leaders. The farmers that could not be reached and or were not available were replaced by the *next available farmer* meeting the criteria. Next available farmer means the farmer whose farm or settlement is the closest to the listed unavailable farmer and that meets the criterion of practicing or not practicing the SRI as the enlisted farmer.

The villages that were involved in Sélingué were nine (out of seventeen villages in total)-Linkétou, Kangaré, Binco, Faraba-coura, Selinkégny, Dialakoro, Kibaru, Kondjiguila and Sanankoro. In Baguinéda, twelve (out of twenty-two) villages were involved-Farakan, Palasso, Mofa, Kokoun, Tieman, Sebela, Sadjouroubougou, Baguinéda-Village, Baguinéda-Camp, Kognimba, Kognini and Dougourakoro.

With regards to the focus group discussions with farmers, three were held in each location. The concerned villages were Kangaré, Selinkégny and Sanankoro for Sélingué, Baguinéda-Village, Tieman and Sébéla for Baguinéda. FGD with group of women transplanters concerned one group in each location, Dialakoro for Sélingué and Kognimba for Baguinéda. The interviews with staff members and field technicians included six people in Sélingué and five people in Baguinéda.

3.2.3. Experiment

The experiment was conducted in Sélingué irrigation scheme with a double purpose: (1) identify the practical constraints including biophysical to the application of the different SRI principles and (2) evaluate the agronomic performance of different SRI application options compared to the conventional practice. The second objective could not be achieved due to unexpected unfolding during the experiment. In fact, despite the fact that experiment site was chosen after consultation with farmers to be sure of irrigation and drainage capabilities, the site was flooded due to conditions explained in the results section.

3.2.3.1. Description

The design used was the Randomized Complete Block Design (RCBD) under two different irrigation methods (alternate wetting and drying-AWD and continuous flooding-CF). Each irrigation methods received four fertilization schemes, zero fertilizer, chemical fertilizer only, organic fertilizer only, and both chemical and organic fertilizers. The number of replications was four. Which gave us 32 experimental units with a plot size of 6*3 ($18m^2$) each.

The experiment activities consisted of soil sample collection, choice of rice variety to be used, land preparation (ploughing and levelling), installation of the nursery, experiment design installation, transplanting of seedlings, refilling, fertiliser applications, weeding, irrigation, panicle initiation and physiological maturity observation, measurement and counting (plant length, tillers and panicles numbers), harvest, yield and yield component computations.

The soil sample collection was done using equipment (auger and cylinders) from the Laboratory Soil-Water-Plant of the Institute for Rural Economy (IER), and following the standard procedures. Five soil samples (four from the corners and one in the middle of field) at 30 cm depth were collected and sent to the Laboratory.

After discussions with the Head of Sélingué Rural Development Office and supervisors, the rice variety IR32307-107-3-2-2 “Wassa” was chosen with regards to its cycle (110 days) and as one of the two mostly used varieties in the area.

Land preparation consisted of ploughing and levelling to allow easy root penetration and irrigation and the nursery was installed afterwards.

The next activity consisted of the experiment design installation. The delimitation of the 32 experimental units with a plot size of 6*3 ($18m^2$) each, one meter between the sixteen plots under both irrigation schemes and six meters between the two categories and neighbouring fields.

Rice seedlings were transplanted on March 9th, 2022, at 2 to 3 leaves stage on 1-2 cm water depth by a group of women transplanters, at 20*20cm spacing and one seedling per hill.

Organic fertilizer and the NPK fertilizer were applied the next days. five days later, an herbicide was applied to prevent weeds development and a week after transplanting, the refilling took place.

The first weeding was done 19 days after transplanting (DAT 19) and was followed by the first topdressing, a day later (DAT 20). The second weeding was performed twenty days after the first one (DAT 39) and the second topdressing was done the following day (DAT 40).

Two weeks after the first topdressing (DAT 35), we starting monitoring for panicle initiation date. The earlier ones were observed 20 days after the first topdressing, 42 days after transplanting (DAT 42). Panicle initiation occurs when three out of ten main tillers have a panicle of around 2mm in length.

Monitoring continued until observation of the physiological maturity on all plots. Upon physiological maturity observation, we planned and proceeded with collecting data to be recorded just before harvest (plant height, tiller and panicle numbers per plant). After these last observations, we then harvested. After harvest, we manually separated the grains from the biomass and weighed them separately at fresh. After weighing, a sample of 150 g of biomass and the grains were put in different cotton bags obtained from the *Laboratoire Sol-Eau-Plante* of IER. All the samples were then transported to the Lab for oven drying at 65 °C for 72 hours. After the oven drying is complete, the remaining yield and yield component data were computed and recorded.

Challenges

While we intended to use field trials to evaluate the agronomic performance of the SRI compared to conventional practices and for modelling purposes (initially), some difficulties occurred and therefore biassed the collected data. Indeed, it was not possible to practice AWD since there was water percolation from the CF plots to AWD plots and from neighbouring fields despite the six meters separation from all sides. This difficulty therefore made data biassed and unusable for the initially set purpose. However, it allowed us to directly witness a challenge that was later on largely reported by farmers.

3.3. Data analysis

The data were analysed using different methods, techniques and approaches to determine the SRI principles adoption level, the factors determining adoption or non-adoption, the technical, technological and management conditions enabling or hindering the application of SRI principles. The statistical software used were the Statistical Package for the Social Sciences (IBM SPSS Statistics 25) and EXCEL.

3.3.1. Adoption level of SRI principles

For the adoption level, we first determined the adoption rates of each SRI principle and the adoption depth, meaning, the number of principles adopted per farmer using frequencies and percentages computations. The same techniques were used to determine the proportion of land allocated to SRI practice per farmer and per location, where appropriate.

3.3.2. Factors determining the adoption or non-adoption of the SRI principles

With regards to determining the adoption or non-adoption factors, we proceeded in two steps. The first step consisted of using frequencies and percentages to determine the factors motivating farmers to practice SRI, those preventing them from its practice and the different characteristics of SRI adopters versus nonadopters. In the second step, we investigated the relationship between SRI adoption and different factors. To do so, the Chi-square test for independence was used for categorical data while the Mann-Whitney U test was used for continuous data.

The factors considered under the categorical analysis were gender, education level, membership of a FBO, access to advisory service, involvement with projects/NGO, access to irrigation water, possibility of drainage, access to organic and chemical fertilisers and finally, engagement in loan.

The factors that were considered under the continuous data analysis were age, household size, score for transport equipment, score for land preparation equipment, total score for all equipment, rice yield, experience in rice production and amount of the loan.

For equipment scoring, we classified the equipment into three categories. The equipment for transport (tractor, tricycle motor and donkey chariot), the equipment for land preparation (plough and motored-cultivator) and other equipment (motored-pump and threshing machine). Scores were attributed to equipment based on the averages of market prices. The equipment scores are indicated in Table 3.1 below.

Table 3.1: Equipment scoring

Categories	Equipment	Score
Land preparation	Motored-cultivator	16.2
	Plough	3.6
Transport	Tractor	35.3
	Tricycle Moto	10.3
	Donkey Chariot	1
Other	Threshing Machine	16.2
	Motored-pump	1.2

3.3.2.1. Pearson's Chi-square test for independence

The Pearson's Chi-square test for independence is used to explore the relationship between two categorical variables (or two set of categorical variables), each of these variables can have two or more categories (Pallant, 2020). The test compares the observed frequencies or proportions of cases that occur in each of the categories with the values that would be expected if there was no association between the two variables being measured (Pallant, 2020). This test is considered as one of the most useful statistics for testing hypotheses when the variables are nominal (McHugh, 2013).

Chi-square test has the assumptions that follow:

- The data in the cells should be frequencies, or counts of cases instead of percentages or some other transformation of the data;
- The levels (or categories) of the variables should be mutually exclusive i.e. a particular subject fits into one and only one level of each of the variables;
- Each subject may contribute data to one and only one cell in the Chi-square;
- The study groups must be independent (unpaired samples);
- There should be two variables, and both measured as categories, usually at the nominal level. Though interval or ratio data arranged into ordinal categories may be used;
- The value of the expected cell counts should be at least five in at least 80% of the cells, and no cell should have an expected count less than one (McHugh, 2013; Pallant, 2020; Rost, 2024).

In this study, the collected data satisfied these assumptions for most of it. For the few that violated the rules, the results were not included or explained empirically.

The Chi-square test was actually used in several studies (Turhan, 2020; Haethaisong et al., 202; Rost, 2024). However, it is worth noting that while the Chi-square test shows the correlation of categorical variables, it does not indicate causation. Therefore, the results were crosschecked, interpreted and explained in the light of empirical observations.

3.3.2.2. Mann-Whitney U test

The Mann-Whitney U Test checks for differences between two independent groups measured on a continuous scale (Pallant, 2020). It is the non-parametric alternative to the Student t-test for independent samples. However, instead of comparing means of the two groups, as in the case of the t-test, the Mann-Whitney U Test compares medians (Pallant, 2020). It converts the scores on the continuous variable to ranks across the two groups. It then evaluates whether the ranks for the two groups differ significantly. As the scores are converted to ranks, the actual distribution of the scores does not matter-non parametric (Pallant, 2020).

The Mann-Whitney U Test therefore assesses whether two sampled groups are likely to be from the same population, or whether they have the same distribution. As null hypothesis, it assumes that the two groups are similar. If they are not then the alternative hypothesis is accepted. As earlier indicated, this test is nonparametric and can be used for small samples as well as large samples (Nachar, 2008; Jankovic, 2022). This test has been applied across a wide range of fields (Nachar, 2008; Wayal, 2016; Vengatesan et al., 2018; Jankovic, 2022; Okoye and Hosseini, 2024).

3.3.3. Technical, technological and managerial conditions enabling or hindering the application of SRI principles

The methodology for this subsection consisted of using empirical observations and information drawn from the focus group discussions with both farmers and administrative staff members in the two locations, to further discuss the implications of the results from the performed analyses in the context of physical, socio-economic and managerial framework.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

Under the first section of this chapter, the presentation of the results from the different analyses conducted and the direct discussion of some the results-where appropriate are made. The first section therefore highlights what our analyses brought to light. The second section contains the general discussion of all the results. It informs of the understanding to be obtained from the statistics, figures and tables contained in the results section. It also mentions their significance, utility and limitations.

4.1. Results

4.1.1. Socio-economic description, location and group differences

4.1.1.1. Socio-economic description of Baguinéda and Sélingué farmers

We conducted 121 individual interviews in the two locations. Sixty-one respondents were interviewed in Baguinéda (42.6 percent were SRI adopters and 57.4 percent nonadopters) and sixty respondents in Sélingué (60 percent SRI adopters and 40 percent nonadopter). In sum, 51 percent of the total respondents were SRI adopters and 49 percent nonadopters. The females represented 13.2 percent of the total respondents (11.5 percent in Baguinéda et 15 percent in Sélingué).

Agriculture is the primary activity of 95 percent of the respondents in both locations. In terms of education level, 22.3 percent of the respondents has no education (instruction) of any type, 25.6 percent reached primary I level (from one to six years of schooling), 9.9 percent reached primary II level (from seven to nine years of schooling), 10.7 percent reached secondary level (general or professional high school), 5 percent reached university, 8.3 attended confessional schools and 18.2 percent attended *adult training program*. The adult training program is designed to teach adults how to write and do computations in order to facilitate their daily activities and improve their general understanding.

With regards to education level (Figure 4.1), the two locations differ on some aspects. The difference can be observed in the following figure which shows that the highest number of respondents without no education (instruction) and the lowest number of respondents that

attended adult training program were recorded in Sélingué. In addition, apart from primary I level the respondents from Baguinéda reached higher level of formal education than those from Sélingué. In sum, 57.3 percent of respondents in Baguinéda attended formal education program against 45 percent for Sélingué.

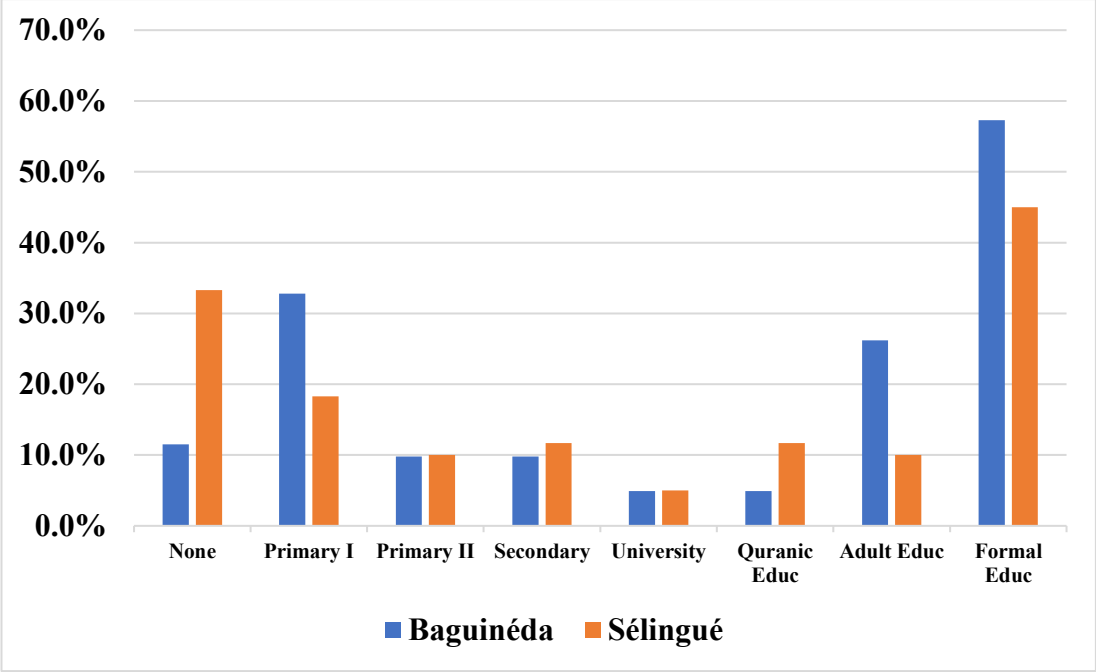


Figure 4.1: Education level in Baguinéda and Sélingué

The youngest respondent in Baguinéda was 21 years old and the oldest was 78 years old against 29 and 79 years old in Sélingué. The average age was respectively 52 and 47 for Baguinéda and Sélingué. The age distribution of the respondents is shown in Figure 4.2, below. It shows that for both locations, most respondents (89.2 percent) were between 31 and 66 years old, 70.24 percent were between 41 and 66 years old.

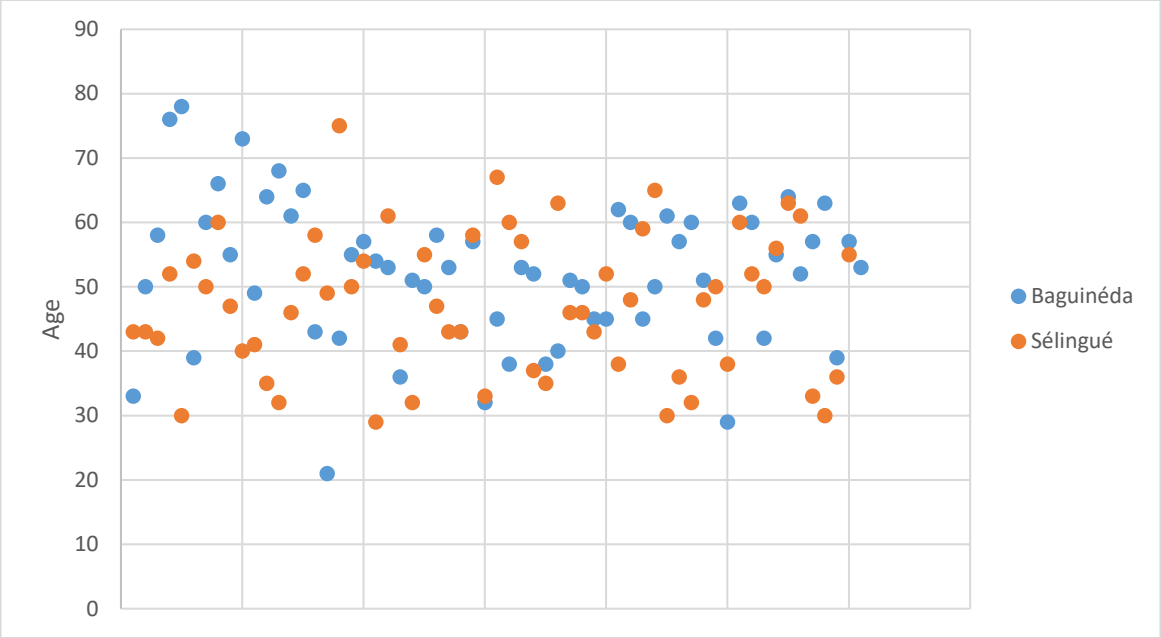


Figure 4.2: Age distribution of the respondents

Regarding the level of equipment (Table 4.1), apart from plough and threshing machine, it is clear that farmers from Baguinéda are more equipped than those from Sélingué. There is one motored-cultivator for around every 6.78 farmers in Baguinéda against 8.57 in Sélingué, one tricycle moto for every 12.2 farmer against 30, one tractor for every 20.33 farmers against none for those interviewed from Sélingué, one donkey chariot for every 2.35 farmers against 6.67.

Table 4.1: Ratio Equipment versus producers

	Motored-cultivator	Motored Pump	Tricycle Moto	Tractor	Donkey Chariot	Plough	Threshing Machine
Baguinéda	6.78	1.44	12.2	20.33	2.35	1.3	10.17
Sélingué	8.57		30		6.67	3.33	8.57
Nonadopters	14.75	1.11	59	19.67	3.69	2	19.67
Adopters	5.17	1.77	10.33		3.26	2.6	6.2

The highlighted figures indicate the amount of equipment per household.

4.1.1.2. Location and group differences

Differences between Baguinéda and Sélingué farmers relative to factors

Results (Table 4.2) indicate that engagement of external workers and access to government advisory service are more frequent with farmers from Baguinéda than those from Sélingué. Membership of a FBO is more common in Sélingué than Baguinéda. The two locations are quite similar when it comes to difficulties to access chemical fertiliser (through government subsidy program) as well as involvement with project/NGO. However, access to organic fertiliser was declared difficult by more famers in Sélingué than in Baguinéda. With regards to water access, irrigation, drainage and inundation, while only twenty percent of the respondents complained of difficult access to irrigation water during the season in Sélingué (against thirty-two percent for the off-season), almost forty percent complained of the same problem in Baguinéda. At the same, more respondents complained of difficult drainage in Sélingué than in Baguinéda. This drainage issue was of a lesser magnitude in during the off-season than the season in Sélingué. Moreover, the occurrence of plot inundation was reported by most respondents during the season than the off-season in Sélingué. This implies that while water access is easier in Sélingué than in Baguinéda, its drainage is less problematic in Baguinéda than it is in Sélingué. Elsewhere, loan taking for production activities is more frequent with famers from Sélingué than Baguinéda. However, the average amount of the loan per year for farmers in Baguinéda is greater than for the farmers in Sélingué.

Table 4.2: Difference between Baguinéda and Sélingué farmers I

Baguinéda	Answer	(%)	Factors	(%)	Answer	Sélingué
	Male	88.5	Gender	85	Male	
	Female	11.5		15	Female	
	Yes	70.5	External worker engagement	58.3	Yes	
		47.5	Membership of a FBO	80		
		91.8	Access to advisory service	63.3		
		37.7	Access to project/NGO assistance	38.3		
		60.7	Easy access to irrigation water during the season	80		
			Easy access to irrigation water during the off-season	68.3		
		85.2	Easy drainage of the plot during the season	26.7		
			Easy drainage of the plot during the off-season	41.7		
			Occurrence of inundation during the season	28.3		
			Occurrence of inundation during the season	8.3		
		96.7	Difficulties to access chemical fertiliser	96.7		
		52.5	Difficulties to access organic fertiliser	61.7		
		50.8	Loan taking for production activities	56.7		

In addition to age distribution, education and level of equipment earlier discussed, results (Table 4.3) indicate that the size of household in Sélingué is bigger than the household size in Baguinéda. However, the total number of workers in the household is greater in Baguinéda than it is in Sélingué. These seemingly conflicting results could be explained by the more frequent engagement of external workers in Baguinéda than Sélingué. The average size of the rice farm is bigger in Baguinéda than in Sélingué. However, households in Sélingué are more land endowed than in Baguinéda. This could be due to the fact that Sélingué is a rural area while Baguinéda is peri-urban and is therefore encroached by the capital city.

Table 4.3: Difference between Baguinéda and Sélingué farmers II

Baguinéda					Sélingué		
Min	Max	Mean	Factors	Mean	Max	Min	
21.00	78.00	52.11	Age	47.35	75.00	29.00	
5.00	75.00	22.90	Total number of people in the family	25.08	68.00	3.00	
1.00	61.00	8.31	Total workers in the family	5.44	28.00	1.00	
1.00	20.00	6.89	Males above fifteen years	6.90	21.00	1.00	
0.00	25.00	6.79	Females above from fifteen years	7.83	21.00	1.00	
1.00	45.00	13.67	Total family members above fifteen years	14.62	38.00	2.00	
0.30	7.01	1.65	Rice farm size (ha)	1.06	4.50	0.25	
0.30	12.25	3.45	Total area for all farms (ha)	8.03	29.00	0.25	
0.00	10.40	1.94	Score for transport equipments	3.85	16.00	0.00	
0.00	37.30	3.01	Score for land preparation equipments	0.49	10.30	0.00	
0.00	92.90	13.38	Total score for all equipments	16.27	90.00	0.00	
0.00	0.00	0.00	Rice yield (paddy) during the Season for the two locations (kg)	0.00	0.00	0.00	
3.00	49.00	29.57	Experience in rice production (years)	25.27	52.00	3.00	
75000	750000	296290	The amount of the loan per year (FCFA)	210705	1000000	44000	

Differences between SRI adopters and nonadopters relative to factors

The results (Table 4.4) indicate that the SRI adopters are mostly male farmers. They also engage external workers more than nonadopters. Membership of a farmer-based organisation is also more common amongst SRI adopters than nonadopters. Government advisory service as well as involvement with project/NGO happened to be more common with SRI adopters than nonadopters. More SRI adopters declared having an easy access to irrigation water during the season. Loan taking for production activities is more frequent with SRI adopters than nonadopters. In addition, the average amount of the loan per year for SRI adopters is more than the average amount for nonadopters.

Table 4.4: Difference between adopters and nonadopters I

Adopters	Answer	(%)	Factors	(%)	Answer	Nonadopters
	Male	95.16	Gender	77.97	Male	
	Female	4.84		22.03	Female	
	Yes	70.97	External worker engagement	57.63	Yes	
		74.19	Membership of a FBO	52.54		
		80.65	Access to advisory service	74.58		
		54.84	Access to project/NGO assistance	20.34		
		85.48	Easy access to irrigation water during the season	54.24		
		56.45	Easy drainage of the plot during the season	55.93		
		96.77	Difficulties to access chemical fertiliser	96.61		
		50	Difficulties to access organic fertiliser	64.41		
		64.52	Loan taking for production activities	42.37		

Furthermore, though the difference might relatively be slight, SRI adopters happened to be younger than nonadopters. The size of household for SRI adopters is bigger than the household size for nonadopters. Similarly, the total workers in the family as well as the total number of family members above fifteen years for SRI adopters is more than that of nonadopters. The average size of the rice farm for SRI adopters is also more than the average rice farm size of nonadopters. Similarly, SRI adopters are more land endowed than nonadopters. Finaly, in terms of level of equipment, SRI adopters possess more equipment than nonadopters. These results are indicated in Table 4.5, below.

Table 4.5: Difference between adopters and nonadopters II

Adopters					Nonadopters		
Min	Max	Mean	Factors	Mean	Max	Min	
29	75	48.47	Age	51.1	78	21	
3	68	26.94	Total number of people in the family	20.88	75	5	
1	61	8.61	Total workers in the family	5.14	37	1	
1	21	7.57	Males above fifteen years	6.19	20	1	
0	23	8.21	Females above from fifteen years	6.36	25	1	
1	38	15.66	Total family members above fifteen years	12.54	45	2	
0.25	4.5	1.51	Rice farm size (ha)	1.28	7.01	0.25	
0.25	29	6.67	Total area for all farms (ha)	4.8	28.75	0.3	
0	16	3.45	Score for transport equipments	2.3	10.4	0	
0	12.3	1.3	Score for land preparation equipments	2.24	37.3	0	
0	90	17.08	Total score for all equipments	12.44	92.9	0	
3	50	27.82	Experience in rice production (years)	27.03	52	3	
44000	1000000	254850	The amount of the loan per year (FCFA)	246200	750000	50000	

4.1.2. Adoption level of different SRI principles

This section shows the rate of adoption of each SRI principle in the two locations and also the depth of adoption (full or partial).

4.1.2.1. Adoption rates of different principles

Amongst the four core principles of the SRI, the wide spacing happened to be the most adopted with 91.94 percent over the two locations (84.62 percent for Baguinéda and 97.22 percent for Sélingué). This was respectively followed by single seedling (72.58 percent), early age transplanting (51.61 percent) and AWD (41.94 percent). The two additional principles (organic fertiliser application and regular weeding) were respectively adopted at 72.58 and 32.26 percents. The second most adopted principle-single seedling was more adopted in Baguinéda (92.31 percent) than it was in Sélingué (58.33 percent). The third most adopted principle-early age transplanting was more adopted in Baguinéda (65.38 percent) than it was in Sélingué (41.67 percent). Similarly, the fourth core principle-AWD was also more adopted in Baguinéda (65.38 percent) than it was in Sélingué (25.00 percent). The two additional principles weeding and organic fertiliser application were also

more frequent in Baguinéda (46.15 and 96.15 percents) than Sélingué (22.22 and 55.56 percents).

These information are summarised in Table 4.6 below.

Table 4.6: Adoption rate of the principles

Practices	Both places	Baguinéda	Sélingué
Alternate wetting and drying	41.94	65.38	25
Single Seedling	72.58	92.31	58.33
Early Age Transplanting	51.61	65.38	41.67
Wide Spacing	91.94	84.62	97.22
Weeding	32.26	46.15	22.22
Organic Fertiliser Application	72.58	96.15	55.56

In sum, these results indicate that taken as whole the SRI principles were more applied in Baguinéda than in Sélingué. In addition, the difference between the two locations is widened when we consider AWD and Single seedling. The reasons for these differences are explained in the general discussion section in light of the results from the analyses of determining factors.

4.1.2.2. Adoption depth of SRI

The adoption depth informs us of the proportion of farmers that adopted different number of principles and the landmass allocated to the practice by farmers.

Results (Table 4.7) show that with regards to the four core principles, while 38.46 percent of farmers adopted them in Baguinéda, only 13.89 percent adopted them in Sélingué (for an average of 24.19 percent). Similarly, both the proportions of farmers that adopted two or three principles in Baguinéda (96.15 and 76.92 percents) are higher than those in Sélingué (72.22 and 38.89 percents).

These results indicate that on average, more principles were adopted by farmers in Baguinéda than in Sélingué.

Table 4.7: Adoption depth of the core principles

	One Principle	Two Principles	Three Principles	Four Principles
Baguinéda	100	96.15	76.92	38.46
Sélingué	100	72.22	38.89	13.89
Both	100	82.26	54.84	24.19

When we include the two additional principles-weeding and organic fertiliser application (Table 4.8), while we can notice that the same pattern between Baguinéda and Sélingué holds, we also witness a decrease in the proportion of full adopters, from 38.46 to 26.92 and 13.89 to 5.56 percents for Baguinéda and Sélingué respectively.

Table 4.8: Adoption depth of the six principles

	One Principle	Two Principles	Three Principles	Four Principles	Five Principles	Six Principles
Baguinéda	100	96.15	96.15	88.46	46.15	26.92
Sélingué	100	83.33	61.11	38.89	13.89	5.56
Both	100	88.71	75.81	59.68	27.42	14.52

In addition, another indicator of the adoption depth is the proportion of farmland allocated to SRI practice over the total rice land of the farmer. The results (Table 4.9) of this exploration indicate that during the season in Baguinéda (exclusive period of practice), 61.54 percent of SRI adopters practice SRI on 100 percent of their rice fields against 30.56 percent in Sélingué for the same period.

The peak practice period in Sélingué is the off-season where 52.72 percent of adopters allocate 100 percent of their rice land to the practice.

Table 4.9: Proportion of land allocated to SRI

	25 or less	25 to 50	50 to 75	75 to less than 100	100 percent	
Baguinéda	0	23.08	11.54	3.85	61.54	Season
Sélingué	30.56	22.22	13.89	2.78	30.56	Season
	5.56	25	16.67	0	52.78	Off-season

The SRI practice is indeed more common during the off-season in Sélingué than it is during the season. Results emphasise that while 66.67 percent of farmers practice SRI during both seasons in Sélingué, 30.56 percent practice exclusively during the off-season against 2.78 only percent for the season.

On average (Table 4.10), these results indicate that an SRI adopter in Baguinéda allocates 77.14 percent of his rice plot to SRI during the season against 53.68 percent during the season and 72.79 percent for the off-season in Sélingué.

Table 4.10: Average rice plot size versus SRI allocation (ha)

		All farmers	Nonadopters	Adopters	Allocated to SRI	Ratio of rice plot allocated to SRI (%)
Baguinéda	Season	1.73	1.71	1.75	1.35	77.14
Sélingué	Season	1.06	0.65	1.36	0.73	53.68
	Off-season				0.99	72.79

4.1.3. Factors determining the adoption or non-adoption of SRI principles at farmers' level

This section tells us what motivate farmers or dissuade them to practice SRI, and which factor at farmers' level facilitate or hinder the adoption of different SRI principles.

4.1.3.1. Motivation for practicing SRI

SRI adopters were asked to indicate the reasons that motivate them to practice SRI and/or the benefits they found in SRI. Results (Table 4.11) indicate that the increase in yield is the primary reason motivating farmers to practice SRI, mentioned by 91.94 percent of SRI farmers. Farmers also mentioned respectively seeds economy (27.42 %), increased tillering (27.42 %), better grain quality (19.35 %), easy field work (17.74 %), fertiliser use efficiency (9.68 %), water use efficiency (6.45 %) and rapid plant growth (4.84 %). Water use efficiency was exclusively mentioned by farmers from Baguinéda. No farmer from Sélingué mentioned the latter reason.

Table 4.11: Motivation for applying SRI

Motivations	Two sites (%)	Baguinéda (%)	Sélingué (%)
Increased tillering	27.42	15.38	36.11
Seeds economy	27.42	42.31	16.67
Increased yield	91.94	96.15	88.89
Easy field work	17.74	11.54	22.22
Fertiliser use efficiency	9.68	19.23	2.78
Water use efficiency	6.45	15.38	0
Better grain quality	19.35	3.85	30.56
Rapid plant growth	4.84	3.85	5.56

These results are similar to those obtained from many other studies (Stoop et al., 2002; Satyanarayana et al., 2007; Zhao et al., 2009; Baskar et al., 2012; Uphoff et al., 2012; Choi et al., 2013; Katambara et al., 2013) confirming that the SRI technology increases yield (can double) and save water. In that sense, Kombe (2012) states that SRI can save up to 64% of irrigation water. Moreover, Katambara et al. (2013) supports that the SRI requires less farm inputs compared to conventional practice and increases tillering. The same author indicates that under SRI, the plant stems are healthier and robust, making them more resistant to pests and diseases, high winds and reduce at the same time the water runoff from the fields with a well-developed root system. These benefits were confirmed during FGD with our respondents.

4.1.3.2. Constraints to practicing SRI

Similarly to motivation, the nonadopters were also asked to indicate the reasons that prevent them from practicing SRI. Results (Table 4.12) indicate that the high transplanting cost (44.07 %) is the most important reason reported by farmers. Indeed, the price for the SRI transplanting method (60 000 – 75 000 FCFA/ha) is higher than the price for non-SRI transplanting method (40 000 – 50 000 FCFA/ha). In addition, farmers (42.37 %) mentioned that SRI requires much more labour than available to them. They also respectively mentioned that SRI requires more water control capacity (25.42 %) and knowledge (25.42), more organic fertiliser (22.03 %), more work and investment for land preparation (22.03 %), more chemical fertiliser (20.34 %) and a compelling agenda (16.95

%). The water control constraint was more emphasised by nonadopters from Sélingué (50.00 %).

Famers indicated that to practice SRI and obtain yield increase, one must in addition to the other conditions, provide all inputs and work in the exact amount and on the exact time it is required. Default to fulfil these conditions, they clearly said it is better to go with the conventional practice. This implies that the certainty associated with the access to these factors has an influence on SRI adoption.

Table 4.12: Reasons for not applying SRI

Reasons	Two sites (%)	Baguinéda (%)	Sélingué (%)
Increased labour requirement	42.37	54.29	25
Compelling agenda	16.95	20	12.5
Land preparation requirement	22.03	28.57	12.5
Chemical fertiliser requirement	20.34	20	20.83
Organic fertiliser requirement	22.03	25.71	16.67
High transplanting cost	44.07	51.43	33.33
Knowledge requirement	25.42	20	33.33
Water control requirement	25.42	8.57	50

These results are in line with findings from Katambara et al. (2013) who states that the application of AWD requires that farmers be able to supply and drain their fields at will, which implies that there should be no seepage from one field to another, which in practice is rare in most irrigated schemes. This becomes more complicated when some farmers practice continuous flooding while others practice SRI and when farming activities are not synchronised as it is in Sélingué and Baguinéda. In addition, the AWD allows more weeds to grow (Katambara et al., 2013) and therefore requires more weeding work as confirmed from our FGD. Moreover, Gathorne-Hardy et al. (2013) indicates that it is ideal to use mechanical equipment for weeds control which were almost non-existent in our study locations. Furthermore, the water control requirement which means irrigating the field with shallow water in order to keep it moist (Laulanie, 1993; Stoop et al., 2002) imposes that the field be well-levelled enough to allow shallow irrigation water to reach the field end from the entry point. This required levelling might practically be difficult for most farmers in

developing countries, especially in Sélingué and Baguinéda where some entire blocks are left out of rice production due to poor levelling.

Famers also indicated that SRI is associated with increased cost and labour. However, this contradicts results from Katambara et al. (2013) who supports that using less seeds and transplanting at wider space reduces the time and work dedicated to the transplanting activity and reducing the costs since less inputs are used. This means that the reported cost and labour increase should be put in context. In the two locations farmers rarely practice weeding-they rather use herbicides and have less irrigation work to do with continuous flooding. Poor infrastructures and lack of equipment certainly make it more difficult for them. With regards to higher transplanting cost and related work, discussions with group of women transplanters revealed that with time, as they get used it, transplanting in row and line and one seedling per plot (SRI) happens to be easier than for the conventional method. However, since they were afraid of it at the beginning they tried discouraging it by higher cost, which never came down.

4.1.3.3. Relationship between SRI adoption and different factors

To statistically find meanings in the previously indicated group differences, Chi-square test for independence was used for categorical variables to check whether there is a significant relationship between these answers and SRI adoption and similarly, the Mann Whitney U test was used for continuous variables to check whether there are statistically significant differences between the two categories.

4.1.3.3.1. Factors associated with SRI practice

The Chi-square test for independence results (Table 4.13) indicate a significant relationship between SRI adoption and education level (formal), gender, membership of a FBO, involvement with project or NGO, the way farmers discovered SRI, easy access to irrigation water and loan taking.

Table 4.13: Chi-Square Tests Results

Factors	Chi-Square value	Continuity correction	Sig.	Sig. continuity	Df	Phi	Cramer's V

				correction			
Education level (formal)	8.09	8.51	**0.04**	0.04	3	0.3	0.3
Gender	7.79	6.36	**0.01**	0.01	1	0.25	0.25
External worker engagement	2.35	1.8	0.13	0.18	1	0.14	0.14
Membership of a FBO	6.12	5.22	**0.01**	0.02	1	0.22	0.22
Access to government advisory service	0.64	0.34	0.42	0.56	1	0.07	0.07
Worker engagement frequency	3.97	4	0.26	0.26	3	0.18	0.18
Access to government advisory service frequency	0.98	1	0.81	0.8	3	0.81	0.81
Involvement with project/NGO	15.27	13.84	**0**	0	1	0.36	0.36
How did you know the SRI	18.81	19.63	**0**	0	2	0.39	0.39
Easy irrigation	14.12	12.67	**0**	0	1	0.34	0.34
Easy drainage	0	0	0.95	1	1	0.01	0.01
Difficulty to access chemical fertiliser	0	0	0.96	1	1	0	0
Difficulty to access organic fertiliser	2.56	2.01	0.11	0.16	1	-0.2	0.15
Loan taking	5.96	5.11	**0.01**	0.02	1	0.22	0.22

In addition, the Mann Whitney U test results (Table 4.14) also revealed a statistically significant differences between the size of the household, the total number of household members involved in production activities, the number females above fifteen years old, total household members above fifteen years old, the size of the rice farm, the total land of the household and transport equipment score of SRI adopters and nonadopters.

Table 4.14: Mann-Whitney U results

Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Adopters	Nonadopters	Adopters	Nonadopters
Age	2060	1.2	0.231	57.27	64.92	50	51
Size of the household	1413.5	-2.16	**0.031**	67.7	53.96	24	17
Total number of workers in the household	1286	-2.71	**0.007**	68.92	51.8	6	4
Males above fifteen years old	1444	-1.87	0.061	66.33	54.47	7	6
Females above fifteen years old	1445.5	-2	**0.046**	67.19	54.5	7	5
Household members above fifteen years old	1458.5	-1.92	**0.054**	66.98	54.72	13.5	10
Size of the rice farm	1278.5	-2.87	**0.004**	69.88	51.67	1.15	0.75
Total farm land	1443	-2.11	**0.035**	67.55	54.12	4.79	3.5
Transport equipment score	1443	-2.03	**0.043**	67.23	54.46	3	2
Land preparation equipment score	1788.5	-0.27	0.79	61.65	60.31	0	0
Total score for all equipment	1471.5	-1.86	0.063	66.77	54.94	11.8	7.2
Experience in rice production	1735.5	-0.49	0.627	62.51	59.42	30	27
Amount of the loan	427.5	-0.98	0.327	34.81	30.1	200000	140000

These results expressed that the more the farmer is educated, the more he is likely to adopt SRI. This is in line with findings from the study of Kabir et al. (2024), conducted in Nigeria and the study of Nonvide (2021). It also corroborated a study conducted in Tanzania by Mhango (2024). The relevance of the education level could be due to the knowledge load of the SRI and the openness of mind that is generally associated with education.

Kabir et al. (2024) also indicated that gender has an influence on SRI adoption, males adopting more than females. In this regard, females are generally less equipped than males, less involved in innovative technologies implementation and spread-out. Female owners are generally those who either inherited from their husbands or fathers. This takes place for most cases at advanced age (Table 4.15) which sometimes goes with less motivation for several things. The table below also indicates that female household heads have less labour and members in their households, less land endowed and take less loan than males.

Table 4.15: Gender-based differences

Gender		Age	Rice Farm Size in Ha	Total Farm size	Transport equipment score	Land prep equipment score	Total score for all equipment	Experience in rice production	The amount of the Loan per Year	Total Size of the Family
Male	Mean	49.34	1.483	6.1107	3.099	2	16.1886	28.14	269456.14	25.47
	Median	50	1	4.27	2	0	10.8	28	200000	21
Female	Mean	52.44	0.5556	3.1525	1.5	0.1875	5.8125	22.81	123750	14.25
	Median	52	0.5	1.5	0.5	0	3	28	117500	10
Total	Mean	49.75	1.3604	5.7195	2.8876	1.7603	14.8165	27.44	251523.08	23.98
	Median	50	1	4	2	0	8.4	28	175000	18

The influence of FBO membership in adoption decisions in agriculture was confirmed by Poornima (2017), Kabir et al. (2024), Jones (2005) and Nonvide (2021). This could be due to the fact that membership of a FBO facilitates access to several benefits for farmers. Amongst these are participation to projects and partnering with NGO, farm input and credit access. This could explain why 74.19 percent of SRI adopters are FBO members against 52.54 percent for nonadopters.

The results relative to the way farmers discovered SRI have all its meaning. In fact, 79 percent of those who participated in SRI trainings applies it against 75 and 36 percents for those who discovered it through government agents' sensitisation and their fellow farmers respectively. This could uncover the efficacy of training and sensitisation for innovation spread-out in these areas. However, the frequency of access to advisory service is debatable. For all farmers, 24.8 percent mentioned that they never or rarely access it, 24.0 percent have less or occasional access it, 43.8 percent indicated the advisory is frequent while only 7.4 said it is more frequent.

While easy access to irrigation water is the wish of all rice farmers, it happened to be a paramount determinant of SRI adoption at farmers' level. In fact, a nonadopter (B59) from Baguinéda said that "*I would like to try SRI but my plot is at the end of the irrigation canal and I have almost no access to water. I start before everybody so as to get some water",* another one (S17) from Sélingué said that "*I practiced SRI twice but later on abandoned it due to lack of water control*". The latter one not only complains of water access but also of the drainage ability. This makes it clear that irrigation water access and control are important factors of SRI adoption. This is similar to the results of Poornima (2017) who mentioned that irrigation facility has a positive influence on SRI adoption and Kabir et al. (2024) who stated that flooding is a major constraint to it.

Though not statistically significant, the results from this table indicates that SRI adopters are younger than nonadopters. The median value for SRI adopters is 50 against 51 for nonadopters. Poornima (2017) found that the age of the household head negatively influences SRI adoption intensity i.e. the older the household head the less likely the adoption. This could signify that young people are more open for new technology adoption

than elderlies. Indeed, the most conservative people generally found in rural communities are amongst the elderlies rather than the youth.

The size of the household, the total number of workers in the household, household members above fifteen and females above fifteen have significant greater median values for SRI adopters than for nonadopters. All these three factors are indicators of the labour available within the household. This confirms that SRI requires more labour than farmers' common practices as they mentioned. In fact, labour requirement happened to be the second most important constraint (mentioned by 42.37 percent of nonadopters) dissuading farmers to adopt SRI. In that sense, a farmer from Baguinéda (B33) mentioned that *"SRI requires much labour and input on time, which I cannot provide because of limited means".* The results with females above fifteen years old being significant against that of males above fifteen years old is likely due to the fact that most of the labour required works-transplanting, refilling, wedding and harvesting in rice fields are generally done by women. However, with the SRI, there are increases in male workers engagement. This also corroborates the findings of Poornima (2017) who stated that labour availability has a positive impact on adoption and Moore et al. (2024) who indicated the major constraints as reasons for not adopting SRI includes limited labour. Furthermore, the study conducted by Kabir et al. (2024) revealed that the major constraints to SRI adoption included limited household size, which determines inhouse labour. Mkubya et al. (2023) also mentioned that the major constraint to SRI adoption was limited access to labour, which increases under SRI versus conventional methods.

Furthermore, our results indicate that farmers with bigger rice farms and those who have more land beyond the rice field are more likely to adopt SRI than those that are less land endowed. Similar results were obtained by Mhango (2024) whose study revealed that land ownership has a significant impact on SRI adoption. In fact, some farmers stated that SRI is reserved for those have more land. It is worth mentioning here that many farmers have their rice fields expressed in several plots. These plots can have different soil types, irrigation and drainage situations, which therefore gives them more possibilities than the less land endowed farmers. In that sense, some farmers indicated they apply SRI on the plots or parts of the plots that are ready to accommodate it. That is a flexibility less land

endowed farmers cannot afford. In addition, land endowment could give more risk margin than the its scarcity.

Finally, transport equipment (tractor, tricycle moto and donkey chariot) ownership also revealed important for SRI adoption. These equipments are used for people, material and input transportation to the rice fields. The bigger ones could also be a source of income for the owners, which might in turn give them more investment capacity. The influence of level of equipment on SRI adoption was confirmed by some other studies. Poornima (2017) found that the level of equipment has a positive impact on SRI adoption, and Moore et al. (2024) indicated that the significant predictors of SRI adoption include household assets.

From the above, we can state that our results corroborated findings from several authors (Poornima, 2017; 2019; Katambara et al., 2013; Noltze et al., 2013; Balamurugan and Rajasekaran, 2019; Nonvide, 2021; Kabir et al., 2024; Mkubya et al., 2023; Mhango, 2024 and Moore et al., 2024. We therefore now know the relevant factors in determining SRI adoption at farmer's level.

However, while these factors happened to determine the adoption of SRI at farmers' level, the question of which particular factor determines the adoption of which particular SRI principle still holds. The next section addresses this.

4.1.3.3.2. Factors associated with different SRI principles

The same two tests were run for each SRI principle separately to determine which factor is related to which particular principle. For adequate space management within the document, the tables and figures for this subsection are in the annex section.

At this point, we could say that this is a new contribution in the field of SRI adoption studies since we have seen no studies addressing the adoption of SRI principles separately and to this level.

Early age transplanting

The results (Annex V-a) of the Chi-Square test for independence indicated significant relationship between early age transplanting and attendance of formal education program,

access to advisory service, involvement with NGO/project, easy drainage of the rice field and engagement in loan. In addition, despite slightly impeding on the Chi-Square test assumptions (33.3 percent of expected count less than five and 1.94 as minimum expected count), inundation also showed significant relationship. This particular factor was clearly emphasised during and interviews and FGD because early age transplanting can be considered only if the plot is prevented from inundation.

The MWU test results (Annex V-a) indicated that the experience in SRI application also happened to be significantly different among the two groups (5.0 against 3.5).

These results indicate that early age transplanting requires three main conditions, knowledge, physical state of the field (or the scheme) and financial means. If the learning is facilitated by the education level of the farmer, and the knowledge provided by the advisory service, involvement with project/NGO and cumulated experience in practicing SRI, still, the physical state of the field (or the scheme) has to allow proper water management on the plot (easy drainage and prevention of inundations) before a farmer could transplant very small seedlings at younger age. In addition, the additional cost of the transplanting and soil conditioning requires some more financial means.

Single seedling

The results (Annex V-b) indicated significant relationship between single seedling and easy drainage and exposure to inundation. The experience in SRI application was also significantly different among the two groups (4.5 against 3.0).

Single seedling was reported as a risky practice by farmers because if the singly seeded plant fails, it would require a refilling work-additional investment. The main risk factor is the water level on the plot whose management involves some two other factors-drainage ability and exposure to inundation.

Alternate wetting and drying

Results (Annex V-c) indicated that access to advisory service, the channel farmer discovered SRI, easy drainage and inundation are significantly related to the application of the AWD. Easy access to irrigation water also happened to be related to the practice (25 percent of expected count less than five and 3.7 as minimum expected count). With regards

to the MWU test results (Annex V-c), the only factor that showed significant difference was the experience in SRI application (5.0 against 3.5).

The advisory service, SRI discovery channel and experience in practicing SRI could provide required knowledge and convince farmers to practice AWD. However, AWD which means irrigating and draining at will therefore requires permanent availability of water at the filed gate and a fully operational drainage system. If these two conditions are not guaranteed, farmers would not find the environment safer for the practice.

Wide spacing

With regards to wide spacing, neither Chi-square test for independence nor the MWU test indicated a significantly related or different factor (Annex V-d).

However, in our discussions, some farmers stated that the spacing is related to the choice of seeds variety. Indeed, some seeds have more tillering ability than others and therefore require more space.

Weeding

Results (Annex V-d) indicated that access to advisory service, the channel of SRI discovery, easy drainage and worker engagement frequency (25 percent of expected count less than five and 3.23 as minimum expected count) are significantly related to weeding practice. In addition, experience in SRI application (5.0 against 4.0) and the amount of the loan (250 000 against 150 000) showed significant difference among the two groups.

These results imply that in addition to acquiring the knowledge about the importance of weeding (advisory service, channel of discovery and experience), the practice requires the absence of water from the plot (easy drainage) and the engagement of additional labour (worker engagement frequency) and the related financial means (loan).

Organic fertiliser application

Results (Annex V-e) indicated that involvement with project/NGO, the SRI discovery channel, easy drainage and to some extent, external worker engagement (25 percent of expected count less than five and 4.94 as minimum expected count), access to advisory service (25 percent of expected count less than five and 3.29 as minimum expected count)

and inundation (33.3 percent of expected count less than five and 1.1 as minimum expected count) happened to be related to organic fertiliser application.

Additionally, the age of the farmer (52 against 42), experience in both rice production (32 against 20) and SRI application (5.0 against 3.0) and, the amount of the loan (250 000 against 125 000) showed significant differences.

Organic fertiliser application happened to be a very complex principle to be adopted since it involved the most important number of factors. It requires knowledge about the necessity of the practice-gained through age, experience in rice production and SRI practice, involvement with project/NGO and SRI discovery channel. It also requires water control (easy drainage and inundation prevention) on the plot because too much water will wash the fertiliser away through runoff and/or infiltration. Additionally, the farmer should afford the price, transport and application costs (loan).

The relationship between the factors and the SRI principles are visualised in Figure 4.3 and Table 4.16 below.

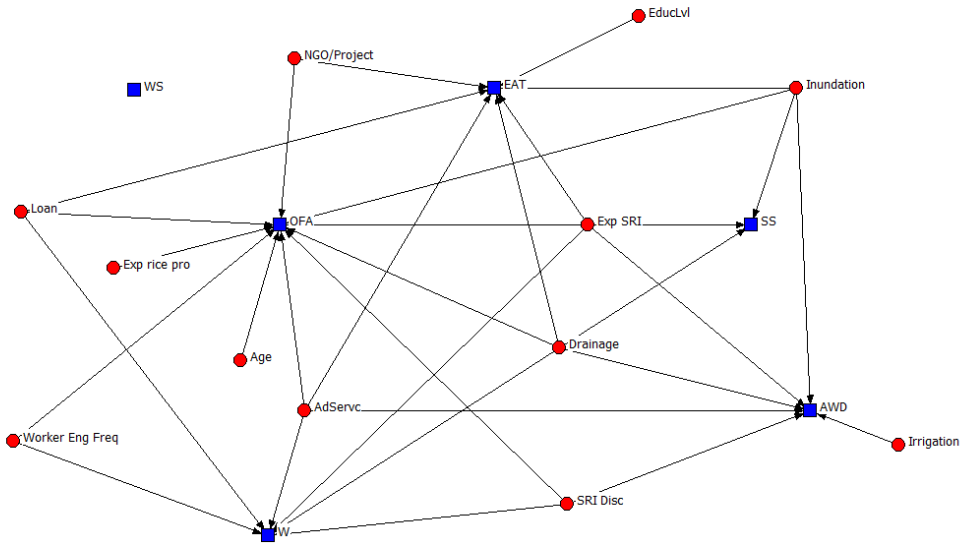


Figure 4.3: Factors and principles' Network

In this figure, the blue squares represent the SRI principles and the red circles represent the different factors. The arrows link the SRI principles to the factors upon which their adoption depend.

Table 4.16: Factors and principles' interaction

	EAT	SS	AWD	WS	OFA	W	Total number of principles
Education level	1	0	0	0	0	0	1
Advisory service	1	0	1	0	1	1	4
Involvement with NGO/Project	1	0	0	0	1	0	2
Drainage	1	1	1	0	1	1	5
Loan	1	0	0	0	1	1	3
Inundation	1	1	1	0	1	0	4
Experience in SRI	1	1	1	0	1	1	5
SRI Discovery channel	0	0	1	0	1	1	3
Irrigation	0	0	1	0	0	0	1
Worker Engagement Frequency	0	0	0	0	1	1	2
Age	0	0	0	0	1	0	1
Experience in rice production	0	0	0	0	1	0	1
Total number of factors	7	3	6	0	10	6	

NB: 1 => Yes; 0 => No

We can read from this graph that out of the six principles, drainage and experience in SRI application contribute to up to five of them. Access to advisory service and inundation influence up to four. Easy access to irrigation, SRI discovery channel and loan contribute to three principles. External worker engagement and involvement with project/NGO contribute to two principles. The factors contributing to only one principle are education level (early age transplanting), easy access to irrigation water (alternate wetting and drying), the age of the farmer and experience in rice production (organic fertiliser application).

The principle that appeals to the most important number of factors is the organic fertiliser application, which relates to ten factors. Early age transplanting requires seven factors. Both alternate wetting and drying and weeding involve six factors. The principle that requires least factors is the single seedling-three factors.

Among the factors we investigated, none happened to be related to the wide spacing adoption.

These results outline the factors that need to be addressed for the adoption of particular principles and at the same time indicate what would likely be the outcome of addressing each particular factor.

4.1.4. Technical, technological and managerial conditions enabling or hindering the application of SRI principles

Results from the previous sections indicates that the adoption of SRI is dependent on some sets of conditions which are awareness and partnership, biophysical conditions of the field (or the scheme), financial and social capacities and management of the schemes. Social capacity herein refers to labour endowment and availability. This fourth condition could in some circumstances be occulted into the financial capacities since engagement of labour (especially external) requires financial means.

The awareness which is acquired by farmers primarily through advisory service, engagement with project/NGO and experience is the very first step to practicing any technology. Secondly, a well-trained and informed farmer can apply SRI only if the physical state of his farm (or of the scheme) allows it. Thirdly, since it is well established that SRI involves additional costs, one should therefore afford it. Finally, even if one fulfils the three previous conditions, if there is no labour available for engagement, one is compelled to go for less labour-costly technologies.

Furthermore, the management of the schemes has an important role to play since it determines a set of other conditions.

4.1.4.1. Partnership, advisory service and awareness delivery

As per their creation objectives, OPIB/ODRS are in charge, in their intervention areas, of providing advisory service to farmers, promote validated good agricultural practices, manage government fertiliser subsidy program, create and facilitate partnership between farmers and other assisting organisations like NGO/Projects, universities and research

institutions. In addition, they facilitate farmers' access to credit for inputs and equipment through partnership with financing institutions. This, altogether, is intended to increase farmers in knowledge and facilitate their access to equipment for better incomes and improved livelihoods.

However, on the delivery of these services, there was a lot of mutual accusations going on. From the discussions with farmers, they complained that the fertiliser subsidy program is not satisfactory. They reported delay in the provision, selectiveness and discrimination. They stated that big producers and farmers in good terms with agents are prioritised over neutral and small land owners. Moreover, they mentioned that the same discrimination and selectiveness continues when it comes to designating participants for new trainings or in case of assistance from a new project for example. They also indicated that it is a small group of farmers benefiting everything while all the rest is left behind. On the other side, agents from both locations indicated their limited number and limited logistic means to properly engage with all farmers directly. They therefore pass through farmer organisation leaders to reach the others and also use Radio communication means. Or, difficult functioning of farmers' organisations, affinity problems and non-involvement of all farmers in the organisations seems not an adequate environment for this option to work properly.

The need for a proper delivery of the advisory service is unhidden, since its importance in contributing in the adoption of SRI principles has been proven. In fact, access to advisory service has been identified as contributing factor in the adoption of four out of the six SRI principles in our study. In addition, engagement with NGO/Projects which itself is related to the advisory service has been identified as contributing factor in the adoption of two out of the six SRI principles. Therefore, the non-effectiveness of these services and collaborations in the study areas hinder SRI adoption.

In line with our findings, Sattler and Nagel (2010) confirm that the components of the diffusion environment are part of the adoption determinants. In addition, Moore et al. (2024) indicated that participation to trainings (which is mostly coordinated through partnership and extension service) is part of the significant predictors of SRI adoption. Kabir et al. (2024) indicated that some of the major constraints to SRI adoption include

inadequate training and limited market access-which could also be facilitated by management staff (extension service). Moreover, Mkubya et al. (2023) showed that access to extension service has positive impact on SRI adoption, and Mhango (2024) confirmed that the knowledge of farmers has significant influence on adoption of SRI.

4.1.4.2. Physical conditions of the schemes

As indicated earlier, the irrigation system in the two locations is gravitational. The Sélingué irrigated scheme is water-supplied by the *Sankarani* river (a tributary of the Niger River) through a hydro-electric dam called *Barrage de Sélingué*. The irrigated scheme is protected from high water levels from the nearby river by elevated dikes. It is equipped with three electric motored pumps at the outlet to drain water out in case of flooding that hinders normal drainage. The Baguinéda irrigated scheme is water-supplied by the Niger river through the dam called "*Barrage des aigrettes*". At its end, the drainage water also returns to the same river. the scheme is also equipped with adapted irrigation and drainage canals to let in safely and drain out water properly for adequate production conditions. With these equipment and installations working properly no flooding should occur in the schemes. However, fifty percent of SRI nonadopters from Sélingué mentioned water level control as a problem dissuading them from practicing SRI. The same issue was mentioned by 8.57 percent of those from Baguinéda. This indicates that there are more drainage related issues in Sélingué than in Baguinéda. However, with regards to irrigation, Sélingué is more water supplied than Baguinéda due to the fact that *Sankarani* is a tributary of the Niger River, which at the same time exposes Sélingué to the occurrence of more floods than Baguinéda. This relative easiness of irrigation explains why rice is produced in Sélingué during the two seasons and only during the rainy season in Baguinéda.

In both locations, field visits and discussions with both management staff and farmers revealed that most farmers have increased their plot size by encroaching on roads, irrigation and drainage canals margins. This has created situations where water infiltrates easily from one plot to another and therefore hindering the application of some SRI principles like EAT, AWD, OFA and weeding to some extent. In fact, we experienced this phenomenon directly by witnessing our trials being flooded in Sélingué during the dry season and despite leaving at least a margin of six meters on each side. This situation

coupled with the non-synchronous activities in the schemes renders water management very complex in the two locations.

Moreover, it is shared by both sides (farmers and OPIB/ODRS) that some sectors in both schemes are not well planned (elevated than the others), which renders their irrigation more difficult despite the water level. These infrastructural problems which further complicate the SRI adoption falls on the responsibility of the government and ODRS/OPIB.

4.1.4.3. Management of the schemes

The management of the irrigated schemes has been detailed in section **3.1.7.** If the architecture and logic of this management is sound, focus group discussions with both sides revealed complicated functioning. In fact, results indicated that different parties hardly execute their responsibilities.

In Sélingué, the primary irrigation and drainage canals (government's responsibility) are not cemented (for most part of it) and that leads to water loss through percolation and infiltration and therefore limits the irrigation capabilities. The electric pumps at the outlet of the irrigated scheme have not been operational since around 2007, according to farmers and confirmed by staff members. This renders the scheme vulnerable to floods through return of water from the main bed of the river. Such floods occur in case of heavy rain and/or release of water by the hydroelectric power dam in order to protect their own infrastructure from too high-water levels.

In addition, in both locations, farmers reported that the maintenance of the secondary irrigation and drainage canals (ODRS/OPIB responsibility) are not properly done. Visiting the two schemes, holes and breaks could easily be observed on parts of these canals. Though the situation seemed worser in Sélingué than in Baguinéda.

Elsewhere, the management staffs of both locations reported that farmers do not respect their engagements as per the operating conditions document "*Cahier des charges*". In fact, despite sensitisation, not all farmers clean and/or repair the tertiary canals. They proceed to rental, borrowing and merchandising of plots. The inheritance is also systematic. During discussions with farmers, these information were not refuted. However, some famers in Sélingué indicated that though cleaning of the tertiary canals falls onto them, it is very

difficult for them to proceed to it because of their depth and the presence of snakes. They added that if one is bitten by a snake, one will have to spend a lot of money to get cure, lose that campaign or eventually one's life. Moreover, in Sélingué, it is common to see farmer-installed pipes cutting through the irrigation or drainage canals, or circulation roads, destined to either irrigate or drain water from the plots, against the rules. This situation was not observed in Baguinéda. However, a few farmers in Baguinéda indicated they use their motored pumps to irrigate their plots in case of dry spell and lack of irrigation water. The difference could be due to the fact that rice production is done in Baguinéda exclusively during the rainy season.

In addition, the operationalisation of the joint committees seems not simple. In fact, it was reported that meetings are not held as frequently as they should be and the renewal of the committee members as for the representatives of the farmers seemed problematic. In Sélingué for example, a committee established in 2009 and that was supposed to be renewed in 2012, was actually renewed till 2016. This clearly reveals disagreement among farmers and the inability of ODRS to assist on that. Such cases were not reported for Baguinéda.

In conclusion, it can be stated that none of the parties in both schemes respect fully their engagement. The non-respect of the management rules by both parties in these two schemes obviously hinders SRI adoption and shall require further and special investigations.

4.1.4.4. Social and financial capacities

In both locations, farmers reported that labour is continuously becoming less available and more costly. In Sélingué, they indicated that it is mostly due to the expansion of artisanal gold mining sites in Sélingué itself and surrounding areas. This attracts mostly the youth that normally constitute the labour for rice production activities and therefore creates labour rarity. In Baguinéda, farmers stated it is mostly because of Baguinéda's closeness to the capital city Bamako, draining its youth and the diversity of activities they can engage into.

While it is commonly agreed by farmers that SRI requires more labour than their conventional practices, labour rarity and its increasing cost does not facilitate its adoption. In fact, 54.29 percent of nonadopters in Baguinéda mentioned that the increased labour requirement of the SRI is part of the reasons they don't apply it. The same factor was mentioned by 25 percent of famers in Sélingué.

Finally, these factors, altogether, are paramount for SRI adoption.

4.2. General discussion

On the course of its expansion globally (Katambara et al., 2013; Noltze et al., 2013) upon its successes, SRI has been introduced in West Africa in recent years (Uphoff, 2016). On the basis of the seemingly more or less favourable comments on its added value, the Government of Mali with some partners has elaborated the National Ten-Year Scaling Up Programme for the System of Rice Intensification (PN-SRI). However, apart from some framed and purely agronomic pre-dissemination trials, no science-based study was conducted in Mali to investigate and determine the adoption level of the SRI principles, identify the factors determining the adoption or non-adoption of the SRI at farmers' level, identify the technical, technological and managerial conditions favouring or hindering the application of the SRI principles. This study aimed to fill that gap. The study therefore tried to answer the question of how SRI is practiced and what are the adoption level and perspectives in the context of climate change in Mali. The baseline hypotheses of the study were that (1) the adoption or non-adoption of the SRI principles depends to some extent on the biophysical conditions of the area, (2) the socioeconomic status of the farmers can determine the adoption of some SRI principles and that (3) the institutional arrangement and governance of the irrigated schemes as well as the technical and technological conditions influence the adoption of some SRI principles. We tried to find answers to these questions looking at two different locations, Sélingué and Baguinéda.

With regards to SRI adoption level in the two locations, results indicated that the SRI principles are more applied in Baguinéda than in Sélingué. When we consider the four core principles of the SRI, we have an adoption rate of 38.46 percent in Baguinéda against 13.89 in Sélingué (for an average of 24.19 percent). Furthermore, results indicated that farmers from Baguinéda allocate more land to the practice of SRI than those from Sélingué. During

the season in Baguinéda (exclusive period of practice), 61.54 percent of SRI adopters practice SRI on 100 percent of their rice fields against 30.56 percent in Sélingué for the same period. The peak practice period in Sélingué is the off-season where 52.72 percent of adopters allocate 100 percent of their rice land to the practice. These results could be explained by the fact that the factors determining the adoption of SRI are more common with farmers from Baguinéda than those from Sélingué. These factors are the education level (formal), gender, membership of a FBO, involvement with project or NGO, the way farmers discovered SRI, easy access to irrigation water, loan taking, the size of the household, the total number of household members involved in production activities, the number females above fifteen years old, the total household members above fifteen years old, the size of the rice farm, the total land owned by the household and transport equipment score.

The findings confirm that farmers from Baguinéda have higher level of education than those from Sélingué, they are more equipped, have bigger rice farms and allocate more land to the practice of SRI. Engagement of external workers and access to government advisory service were more frequent with farmers from Baguinéda than those from Sélingué. Membership of a FBO was more common in Sélingué than Baguinéda. The two locations were quite similar when it comes to difficulties to access chemical fertilizer (through government subsidy program) as well as involvement with project/NGO. Results also indicated that access to irrigation water was more difficult in Baguinéda than Sélingué. The primary reason for this is that Sélingué is located upstream the river while Baguinéda is downstream. This at the time makes water management more difficult in Sélingué than Baguinéda, due to faulty infrastructures in the two locations, but especially in Sélingué. It also explains why SRI is more practiced during the offseason than during the season in Sélingué and why it is not compulsory in Baguinéda during the offseason. The major infrastructural problems reported in the two locations are the non-maintenance of the canals and the equipment by both farmers and the management structures, the existence of anarchic farmers'-created canals on the schemes (in Sélingué), no cementing of the primary irrigation canals and the nonfunctioning of the outlet electric pumps (in Sélingué), the encroachment on dikes, networks and road margins.

In addition to these socio-economic, informational and biophysical related results, our findings revealed that the management of the schemes has an important role to play in the adoption of the SRI. Our results indicated that none of the parties in both schemes respect fully their engagement, and the non-respect of these management rules by both parties in these two schemes obviously hinders SRI adoption. The non respect of these engagements shall require further and special investigations.

In sum, these results confirm our hypotheses that the adoption or non-adoption of the SRI principles depends to some extent on the biophysical conditions of the area, the socioeconomic status of the farmers and the institutional arrangement and governance of the irrigated schemes as well as the technical and technological conditions.

In addition to these results which might seem general and broader, what we especially did in this study was to try to single out the very particular factors that determines the adoption of each single principle of SRI. These results revealed that EAT is associated with attendance of formal education program, access to advisory service, involvement with NGO/project, easy drainage of the rice field, occurrence or exposure to inundation and engagement in loan. Single seedling is associated with easy drainage and exposure or occurrence of inundation. AWD is associated with access to advisory service, the channel farmer discovered SRI, easy drainage, inundation and experience in SRI application. Weeding is associated with access to advisory service, the channel of SRI discovery, easy drainage and worker engagement frequency, experience in SRI application and the amount of the loan. OFA is associated with involvement with project/NGO, the SRI discovery channel, easy drainage, external worker engagement, inundation, experience in both rice production and SRI application, and the amount of the loan. The analyses did not associate wide spacing to any of the factors we considered. However, during FGD some farmers stated that the spacing is related to the choice of seeds variety. Indeed, some seeds have more tillering ability than others and therefore require more space. These results are very meaningful in terms of understanding which factors should be considered depending on which particular SRI principle is targeted and what would likely be the outcome of addressing of each factor.

Furthermore, these results helped understand that EAT transplanting requires three main conditions, knowledge, physical state of the field (or the scheme) and financial means. If the learning is facilitated by the education level of the farmer, and the knowledge provided by the advisory service, involvement with project/NGO and cumulated experience in practicing SRI, still, the physical state of the field (or the scheme) has to allow proper water management on the plot (easy drainage and prevention of inundations) before a farmer could transplant very small seedlings at younger age. In addition, the additional cost of the transplanting and soil conditioning requires some financial means. Single seedling is reported as a risky practice by farmers because if the singly seeded plant fails, it would require a refilling work-additional investment. The main risk factor is the water level on the plot whose management involves some two other factors-drainage ability and exposure to inundation. AWD which means irrigating and draining at will requires permanent availability of water at the filed gate and a fully operational drainage system. If these two conditions are not guaranteed, farmers would not find the environment safer for the practice. Results also explain that in addition to acquiring the knowledge about the importance of weeding (advisory service, channel of discovery and experience), the practice requires the absence of water from the plot (easy drainage) and the engagement of additional labour (worker engagement frequency) and the related financial means (loan). With regards to OFA, it happened to be a very complex principle to be adopted since it involves the most important number of factors. It requires knowledge about the necessity of the practice-gained through age, experience in rice production and SRI practice, involvement with project/NGO and SRI discovery channel. It also requires water control (easy drainage and inundation prevention) on the plot because too much water will wash the fertilizer away through runoff and/or infiltration. Additionally, the farmer should afford the price, transport and application costs (loan).

We can conclude from these results that if one considers SRI as a package and aims at the adoption of all its principles (full adoption), it would be a very complex and challenging aim to reach since the fulfilment of all the required conditions-above stated in one location is almost impossible, or at least very difficult.

CHAPTER FIVE

5.0. CONCLUSION AND RECOMMENDATIONS

This fifth chapter contains the conclusion that could be drawn from the study and the recommendations whose implementation we think can improve the adoption level of the SRI in the two locations and other locations with similar context. It also contains recommendations for further studies.

5.1. Conclusion

This research investigated the practice of SRI and the adoption perspective of its principles in the context of climate change in Mali. It particularly looked at the adoption level of SRI principles, the factors determining their adoption or non-adoption at farmers' level, the technical, technological and managerial conditions enabling or hindering the application of SRI principles in the chosen areas. The study hypothesised that biophysical, socioeconomic, institutional, managerial, technical and technological conditions of farmers and their environment influence the adoption of SRI principles and their application. Theses hypotheses were confirmed by the study results. From the findings, we could confirm and conclude that socioeconomic status of the farmers, like education level, household size, access to credit, labour, land and equipment availability and endowment among others determine to some extent the adoption or non-adoption of SRI principles. The results also indicated that the biophysical state of the farmer's field and the whole or part of the irrigated scheme in terms of the functioning of its irrigation and drainage equipment and networks is very crucial to the adoption of SRI principles. Moreover, the governing of the irrigated schemes, the relationship between farmers and the staff, the inner functioning of farmers' organisations, the implementation and respect of agreement documents also impact considerably the adoption of SRI principles.

The main point of this study is that strategies and programmes aiming at promoting the adoption of SRI in the study areas, or any place with similar context, should not be limited to educating famers on how SRI works and expect them to apply it. Rather, such strategies and programmes should include components addressing other aspects including biophysical, technical, technological and managerial environment as revealed in this study. This study will, therefore, be very useful in informing such programmes.

5.2. Recommendations

In light of the main findings from this study and their implications, the following specific recommendations could be formulated:

For interventions aiming at promoting the adoption of SRI, in general

- Reference studies should be conducted in areas where SRI promotion is intended before any implementation;
- Such studies should inform of the existing infrastructural, biophysical, technical, technological and managerial problems in the area;
- The intervention should therefore address all eventually raised issues that might deter farmers from practicing SRI principles;
- Evaluation studies should be conducted on time to understand the adoption process and level, and address emerging issues.

For interventions aiming at promoting the adoption of SRI, in Baguinéda and Sélingué

- Farmers should be assisted in structuring and entertaining their organisations for better delivery and effective participation in irrigated schemes governing;
- More farmers should get a chance to participate in SRI trainings sessions and involve with partners;
- Access to equipment should be facilitated to compensate increasing difficult access to labour, especially the SRI mechanical weeder;
- Maintenance of the irrigation and drainage networks should be effectively done by both parties to reduce related problems on the schemes;
- Irrigation and drainage canals should be rehabilitated;
- Fertiliser subsidy programme should be improved to facilitate access;
- Farming calendar should be respected to facilitate water management;
- Management staffs should be given necessary logistics means and reinforced in competences to properly deliver the required services.

For further studies

- Further studies could look at the deep root causes of mistrust between farmers and management staffs and the efficient utilisation of the schemes' maintenance funds.

REFERENCES

Abebe, T. H. (2019). The Derivation and choice of appropriate test statistic (z, t, f and chi-square test) in research methodology. *J. Math. Lett*, 5(3), 33-40.

Adhikari, A., Shah, R., Baral, S., & Khanal, R. (2011). Terminologies Used in Climate Change. International Union for Conservation of Nature, Retrieved from http://iucnnepal.org on July 10, 2021

Africare Mali. (2008). The System of Rice Intensification (SRI) First Experiences from Timbuktu – Mali; Farmer-led SRI test in Goundam – 2007/2008. Africare Mali, Bamako, Mali. http://sri.ciifad.cornell.edu/countries/mali/MaliAfricare200708.pdf

Africare Mali et SAC Goundam (2009) Fiche Technique pour le Système de Riziculture Intensive (SRI) à Tombouctou, Mali. Africare Mali, Bamako, and Secteur de l'Agriculture du Cercle (SAC) de Goundam, DRA Tombouctou, Tombouctou, Mali. http://sri.ciifad.cornell.edu/countries/mali/extmats/Mali_SRI_Fiche_Technique09.pdf

Alcon, F., S. Tapsuwan, J.M. Martínez-paz, R. Brouwer, and M.D. De Miguel. (2014). Forecasting deficit irrigation adoption using a mixed stakeholder assessment methodology. *Technological Forecasting and Social Change* 83: 183–193.

Alexander, K., and S. Larson. (2016). Smallholder farmer decision-making and technology adoption in southern Lao PDR: opportunities and constraints. Report for ACIAR ASEM/2014/052 project Smallholder farmer decision-making and technology adoption in southern Laos: opportunities and constraints. Canberra, ACT, Australia: ACIAR. https://sites.google.com/view/acrtechnologyadoption/project-reports. Accessed on 10.02.2024

Alexander, K., L. Parry, P.Thammavong, S. Sacklokham, S. Pasouvang, J. Connell, T. Jovanovic, M. Moglia, S. Larson, and P. Case. (2018). Rice farming systems in Southern Lao PDR: Interpreting farmers' agricultural production decisions using Q methodology. *Agricultural Systems* 160: 1–10.

Alexander, K. S., Greenhalgh, G., Moglia, M., Thephavanh, M., Sinavong, P., Larson, S., Jovanovic, T., & Case, P. (2020). What is technology adoption? Exploring the agricultural research value chain for smallholder farmers in Lao PDR. *Agriculture and Human Values*, *37*(1), 17–32. https://doi.org/10.1007/s10460-019-09957-8

Anas, I. and Sato S. (2008). System of Rice Intensification Extension in Indonesia, World Bank Global Learning Network, Conference.

Anas, I., Rupela, O., Thiyagarajan, T.M. and Uphoff, N. (2011a). A review of studies on SRI effects on beneficial organisms in rice soil rhizospheres. Paddy and Water Environment. 9. 53-64. doi:10.1007/s10333-011-0260-8.

Anas, I., Barison, J., Kassam, A., Mishra, A., Rupela, O.P., Thakur, A., Thiyagarajan, T.M. and Uphoff, N. (2011b). The System of Rice Intensification (SRI) as a beneficial human intervention into root and soil interaction. *Jurnal Ilmu Tanah dan Lingkungan*. 13. 72. 10.29244/jitl.13.2.72-88.

Ayele, S., A. Duncan, A., Larbi, and T.T. Khanh. (2012). Enhancing innovation in livestock value chains through networks: Lessons from fodder innovation case studies in developing countries. *Science and Public Policy*. 39: 333–346.

Balamurugan V. and Rajasekaran R. (2019). A study on constraints experienced by the farmers in adoption of System of Rice Intensification (SRI) technologies. *Plant Archives* Vol. 19 No. 1, 2019 pp. 1902-1904.

Baskar, P., Siddeswaran, K., Thavaprakaash, N. and Muthukrishnan, P. (2012) Performance of nursery methods and crop geometry of rice varieties under rice lowlands. *Madras Agricultural Journal*, 99, 563-566.

Binswanger-Mkhize, H. P., & Savastano, S. (2017). Agricultural intensification: The status in six African countries. Food policy, 67, 26–40. https://doi.org/10.1016/j.foodpol.2016.09.021

Bodegom, A. J. Van, & Satijn, B. (2015). Climate Change Profile of Mali. Netherlands Commission for Environmental Assessment. July, 2015

Brown, P.R., I. Nuberg, and R. Llewellyn. (2017). Stepwise frameworks for understanding the utilisation of conservation agriculture in Africa. *Agricultural Systems* 153: 11–22.

Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005). The Economic and Food Security Implications of Climate Change in Mali. *Climatic Change*, 68, 355-378. https://doi.org/10.1007/s10584-005-6014-0

Cafer, A.M., and Rikoon J.S. (2018). Adoption of new technologies by smallholder farmers: The contributions of extension, research institutes, cooperatives, and access to cash for improving Tef production in Ethiopia. *Agriculture and Human Values* 35 (2018): 685–699. https://doi.org/10.1007/s10460-018-9865-5

Carlson, K.M., Gerber, J.S., Mueller, N.D., Herrero, M., MacDonald, G.K., Brauman, K.A., Havlik, P., O'Connell, C.S., Johnson, J.A., Saatchi, S., West, P.C., (2017). Greenhouse gas emissions intensity of global croplands. *Nat. Clim. Change* 7, 63. https://doi.org/10.1038/NCLIMATE3158.

Choi, J.D., Park, W.J., Park, K.W. and Lim, K.J. (2013). Feasibility of SRI methods for reduction of irrigation and NPS pollution in Korea. *Paddy and Water Environment*, 11, 1-8. http://link.springer.com/article/10.1007/s10333-012-0311-9.

Choi, J.D., Kim G.Y., Park W.J., Shin M.H., Choi Y.H., Lee S., Kim S.J. and Yun D.K. (2014). Effect of SRI water management on water quality and greenhouse gas emissions in Korea. *Irrigation and Drainage*, 63: 263-270.

Dill, J., Deichert, G. and Le, T.N.T., (2013). Promoting the System of Rice Intensification: Lessons Learned from Trà Vinh Province, Vietnam. GIZ and IFAD, Hanoi. http://infoagro.net/archivos_Infoagro/Regatta/biblioteca/VN-GIZreportonLesson.pdf

Doss, C.R. (2006). Analyzing technology adoption using microstudies: Limitations, challenges, and opportunities for improvement. *Agricultural Economics* 34 (3) : 207–219.

Styger E., Attaher M. A., Guindo H., Ibrahim H., Abba I., Diaty M., Traore M. and Mahamar M. S. (2009). Fiche Technique pour le Système de Riziculture Intensive (SRI) à Tombouctou, Mali. Africare Mali, Bamako, et Secteur de l'Agriculture du Cercle (SAC) de

Goundam, DRA Tombouctou, Tombouctou, Mali, p. 22. http://sri.ciifad.cornell.edu/countries/mali/extmats/Mali_SRI_Fiche_Technique09.pdf

Clarke, E., T. M. Jackson, K.. Keoka, V. Phimphachanvongsod, P. Sengxua, P. Simali, and L. J. Wade. (2018). Insights into adoption of farming practices through multiple lenses: an innovation systems approach. *Development in Practice* 28 (8)1–16.

Clarke, E., T. Jackson, K. Keoka, and V. Phimphachanvongsod. (2016). Study of farmer experiences and approaches with mechanised dry direct seeding in Savannakhet province: Crop-livestock systems platform for capacity building, testing practices, commercialisation and community learning. CSE/2014/086. ACIAR, Canberra.

Clemence T. Nhliziyo. (2015). A Review of Agricultural and Food Policies in Mali, A Paper prepared for BEAT/Alliance for a Green Revolution in Africa Project.

FAO. (2015): FAO Statistical Pocketbook 2015, Food and Agriculture Organization of the United Nations, Rome, 2015, http://www.fao.org/faostat/en/#data

FAO. (2017). Country Fact Sheet on Food and Agriculture Policy Trends, for Mali. https://www.fao.org/in-action/fapda

FAO-APRAO, (2013). Éclairages sur la contribution d'APRAO au développement du secteur rizicole au Mali. https://www.fao.org/fileadmin/user_upload/spid/docs/Mali/FAO-APRAO-FactSheet-Mali_LORES.pdf

FAOSTAT. (2020). Statistical Database. Food and Agriculture Organization of the United Nations, Rome.

Feder, G., R.E. Just, and D. Zilberman. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33: 255–298.

Gathorne-Hardy, A. Narasimha R. D.,Venkatanarayana M. and Harriss-White B. (2013). A Life Cycle Assessment (LCA) of Greenhouse Gas Emissions from SRI and Flooded Rice

Production in SE India, *Taiwan Water Conservancy Journal* 61 (4), pp. 111-125. http://140.112.63.162/pdf/61/61-4-110-125.pdf

German, L., J. Mowo, and M. Kingamkono. (2006). A methodology for Tracking the ‘‘fate’’ of technological interventions in agriculture. *Agriculture and Human Values* 23 : 353–369.

Gilles, J. L., J. L Thomas, C.Valdivia and E. S. Yucra. (2013). Laggards or leaders: conservers of traditional agricultural knowledge in Bolivia. *Rural Sociology* 78: 51–74.

Griliches, Z. (1957). Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica* vol. 25

Haethaisong, Waeowan & Duangchan, Chaimongkol & Wechakama, Maneenate. (2023). The relationship between the shape of SPARC rotation curves to the galactic mass model: a chi-square test of independence. Journal of Physics: Conference Series. 2653. 012023. 10.1088/1742-6596/2653/1/012023.

Hailu, B.K., B.K. Abrha, and K.A. Weldegiorgis. (2014). Adoption and Impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics* 2: 91–106.

Héritier Rutabara (2017), La perception de l'entretien du réseau de drainage et sa solution selon les agriculteurs-Étude de cas de Baguinéda Amont (OPIB / Mali), Master thesis, 2iE, Ouagadougou.

Hogset, H. 2005. Social networks and technology adoption. *American Agricultural Economics Association Annual Meeting*, July 24-27, 2005. Providence, Rhode Island.

IPCC, (2007). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate ed M L Change et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

IPCC, (2012): Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J.

Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564.

IPCC, (2019): Annex I: Glossary [Weyer, N.M. (ed.)]. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In Press

Ismail, A.M., Johnson, D.E., Ella, E.S., Vergara, G.V. and Baltazar, A.M. (2012). Adaptation to flooding during emergence and seedling growth in rice and weeds, and implications for crop establishment. *AoB Plants*, 2012, pls019. doi:10.1093/aobpla/pls019

Jankovic, Slobodan. (2022). Tests for Comparison of Two Groups: Student's T-test, Mann-Whitney U-test and Chi-square Test. International Journal on Biomedicine and Healthcare. 10. 134. 10.5455/ijbh.2022.10.134-136.

Jones, K.M. (2005). Technology adoption in West Africa: adoption and dis-adoption of soybeans on the Togo-Benin border. Master of Science dissertation, Department of Natural Resource Management. Raleigh, NC: North Carolina State University, USA.

Kabir, A. M., Murtala, N., Garba, M., & Abu, I. A. (2024). Determinants of Adoption of System of Rice Intensification (SRI) Practices Among Male Rice Farmers in Kano State, Nigeria. Nigerian Journal of Agriculture and Agricultural Technology, 4(4B), 270–281. https://njaat.com.ng/index.php/njaat/article/view/921

Karki, S. (2010). System of Rice Intensification: An Analysis of Adoption and Potential Environmental Benefits. M.Sc. Thesis. Norwegian University of Life Sciences, Ås, Norway.

Katambara, Z. , Kahimba, F. , Mahoo, H. , Mbungu, W. , Mhenga, F. , Reuben, P. , Maugo, M. and Nyarubamba, A. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. *Agricultural Sciences*, 4, 369-375. doi: 10.4236/as.2013.48053.

Katayama, T. (1951). *Ine mugi no bungetsu kenkyu* (Studies on Tillering in Rice, Wheat and Barley). Yokendo Publishing, Tokyo.

Kebede, Y. (1992). Risk behavior and new agricultural technologies: the case of producers in the central highlands of Ethiopia. *Quarterly Journal of International Agriculture*. 31:269–284

Kebede, W. M. , & Tadesse, D. (2015). Determinants Affecting Adoption of Malt-Barley Technology: Evidence from North Gondar Ethiopia. Journal of Food Security, 3(3), 75-81.

Kimura, S.D. (2009). Methane and nitrous oxide emissions from paddy rice fields in Indonesia: Comparison of SRI and surrounding conventional fields. http://www.slideshare.net/SRI.CORNELL/0890-dorotheamethane-and-nitrousoxide-emissions-from-paddy-rice-fields-in-indonesia-comparison-of-sri-andsurrounding-conventional-fields

Knowler, D. (2015). Farmer adoption of conservation agriculture: A review and update. In Conservation agriculture, ed. M. Farooq and K.H.M. Siddique, 621–642. Berlin: *Springer*. https://doi.org/10.1007/978-3-319-11620 -4_23.

Knowler, D., and B. Bradshaw. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32: 25–48.

Kombe, E. (2012). The system of rice intensification (SRI) as a strategy for adapting to the effects of climate change and variability: A case study of Mkindo Irrigation Scheme in Morogoro, Tanzania, MSc. Dissertation, Sokoine University of Agriculture, Morogoro.

Laboratoire Sol-Eau-Plante (LABOSEP). (2000). Zones Agro-climatiques du Mali. Institut d'Économie Rurale (IER). Mali

Laulanié, H. 1993. Le système de riziculture intensive malgache. *Tropicultura*, 11,3,110-114

Linquist, B.A., Adviento-Borbe, M.A., Pittelkow, C.M., van Kessel, C., van Groenigen, K. J., (2012). Fertilizer management practices and greenhouse gas emissions from rice

systems: a quantitative review and analysis. *Field Crops Research* 135, 10–21. doi: 10.1016/j.fcr.2012.06.007.

Leeuwis, C., and A. Van Den Ban. (2004). Communication for rural innovation: Rethinking agricultural extension. Oxford: Blackwell Science

MacFarland, Thomas and Yates, Jan. (2016). Mann–Whitney U Test. 10.1007/978-3-319-30634-6_4.

Marra, M., D.J. Pannell, and A.A. Ghadim. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems* 75: 215–234.

Maya Moore, Kimmerling Razafindrina, V. Ernesto Méndez & Meredith T. Niles (2024) An analysis of the adoption of the "system of rice intensification" (SRI): why a homegrown technique has yet to take seed among rice farmers in Madagascar, Cogent Food &Agriculture, 10:1, 2319932, DOI: https://doi.org/10.1080/23311932.2024.2319932

McHugh, M. L. (2013). The chi-square test of independence. *Biochemia medica*, 23(2), 143-149.

Mhango Solomon S. (2024). Factors Influencing Adoption of System of Rice Intensification among Smallholder Farmers in Mvomero District, Tanzania. International Journal of Multidisciplinary Research and Analysis. ISSN(print): 2643-9840, ISSN(online): 2643-9875, DOI : https://doi.org/10.47191/ijmra/v7-i02-33

Ministère de la Sante et de l'Environnement. (2008). Elements Of National Policy For Adaptation To Climate Change, Mali.

Ministère de la Sante et de l'Environnement. (2011). Politique nationale sur les changements climatiques, Mali.

Mkubya R.W., Damas P. and Mahoo H.F. (2023). Socio-Economic Factors Influencing the Adoption of SRI among Smallholder Rice Irrigation Farmers in Morogoro Region, Tanzania. Tanzania Journal of Agricultural Sciences (2023) Vol. 22 No. 1, 169-183

Nachar, Nadim. (2008). The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution. *Tutorials in Quantitative Methods for Psychology*. 4. 10.20982/tqmp.04.1.p013.

Noltze, M., Schwarze, S. and Qaim, M. (2013) Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. *Ecological Economics*, 85, 59-68.

Nonvide G. M. A. (2021). Adoption of agricultural technologies among rice farmers in Benin. *Wiley*. Rev Dev Econ. 2021;00:1–19. doi : 10.1111/rode.12802

Okoye, Kingsley & Hosseini, Samira. (2024). Mann–Whitney U Test and Kruskal–Wallis H Test Statistics in R. 10.1007/978-981-97-3385-9_11.

Ovwigho, B.O. (2013). A framework for measuring adoption of innovations: improved cassava varieties in Delta State Nigeria. *Extension Farming Systems Journal* 9: 171–177.

Pallant, J. (2020). SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS (7th ed.). Routledge. https://doi.org/10.4324/9781003117452

Pannell, D., Marshall, G., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R. (2006). Understanding and promoting adoption of conservation practices by rural landholders. Australian Journal of Experimental Agriculture - AUST J EXP AGR 46: 1407–1424. 10.1071/EA05037.

Park, S.E., Marshall, N.A., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E. and Fleming A. (2012). Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change*, Volume 22, Issue 1, 115-126, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2011.10.003.

Pattanayak, S.K., D.E. Mercer, E. Sills, and J.C. Yang. (2003). Taking stock of agroforestry adoption studies. *Agroforestry Systems* 57:173–186.

Philp, J. N. M., Vance, W., Bell, R. W., Chhay, T., Boyd, D., Phimphachanhvongsod, V. and Denton, M. D. (2019). Forage options to sustainably intensify smallholder farming systems on tropical sandy soils. A review. *Agronomy for Sustainable Development* 39: 30.

Poornima Varma (2017): Adoption of System of Rice Intensification under Information Constraints: An Analysis for India, *The Journal of Development Studies*. DOI: 10.1080/00220388.2017.1336541

Poornima Varma (2019) Adoption and the impact of system of rice intensification on rice yields and household income: an analysis for India. *Applied Economics*. 51:45, 4956-4972, DOI: 10.1080/00036846.2019.1606408. https://doi.org/10.1080/00036846.2019.1606408

Reddy, D.N. and Mortkori, V. (2013). "SRI cultivation in Andhra Pradesh: Achievements, problems and implications for GHGs and work," in: Harriss-White, B. (ed.), Technology, Jobs and A Lower Carbon Future: Methods, Substance and Ideas for the Informal Economy (The Case of Rice in India), 160-192, Delhi, 2013. http://www.southasia.ox.ac.uk/sites/sias/files/documents/Conference%20Book.pdf

Rogers, E.M. (2003). Diffusion of innovations, 5th ed. New York: Freel Press.

Rost, Jim. (2024). Analyzing Student Success Outcome Variables in Higher Education Utilizing the Chi-Square Test of Independence. International Journal of Higher Education. 13. 100. 10.5430/ijhe.v13n2p100.

Sattler, C., and U.J. Nagel. (2010). Factors affecting farmers' acceptance of conservation measures – A case study from north-eastern Germany. *Land Use Policy* 27: 70–77.

Sheahan, M., Barrett C. B., (2017). Ten striking facts about agricultural input use in Sub-Saharan Africa. *Food Policy*. 67, 12-25, https://doi.org/10.1016/j.foodpol.2016.09.010.

Satyanarayana, A., Thiyagarajan, T. and Uphoff, N. (2007) Opportunities for water saving with higher yield from the system of rice intensification. *Irrigation Science*, 25, 99-115. doi:10.1007/s00271-006-0038-8

Selim Kılıc (2016). Chi-square Test. Psychiatry and Behavioral Sciences, 6 (3), 180-2. doi:10.5455/jmood.20160803110534

Selim Kılıc (2016). Chi-square Test. Psychiatry and Behavioral Sciences, 6 (3), 180-2. doi:10.5455/jmood.20160803110534

Sidibe, A, Olabisi, LS, Doumbia, H, Toure, K, Niamba, CA. (2021). Barriers and enablers of the use of digital technologies for sustainable agricultural development and food security: Learning from cases in Mali. *Elementa: Science of Anthropocene* 9 (1). DOI: https://doi.org/10.1525/elementa.2020.00106

Smale, M., P.W. Heisey, and H. Leathers. (1995). Maize of the ancestors and modern varieties: The microeconomics of high-yielding variety adoption in Malawi. *Economic Development and Cultural Change* 43 (2): 351–368.

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

Styger E. (2010a). Scaling-up the System of Rice Intensification (SRI) in Goundam and Dire, Timbuktu 2009/2010. Africare Goundam and Africare Bamako, Bamako, Mali, 35p

Styger E. (2010b). Introducing the System of Rice Intensification (SRI) to irrigated systems in Gao, Mopti, Timbuktu and to rainfed systems in Sikasso, 2009/2010. Consultancy report for Abt Associates, Bamako, Mali

Styger E., Ibrahim H. (2009) The System of Wheat Intensification (SWI): Initial Test by Farmers in Goundam and Dire, Timbuktu, Mali 2009. Timbuktu Food Security Initiative (TFSI), Africare and USAID, Bamako, Mali. http://sri.ciifad.cornell.edu/countries/mali/MaliSWIAfricareRpt090909.pdf

Styger E. and Traoré G. (2018). 50,000 Farmers in 13 Countries: Results from Scaling up the System of Rice Intensification in West Africa; Achievements and Regional Perspectives for SRI; SRI-WAAPP Project Summary Report, 2014-2016; West Africa

Agriculture Productivity Program (WAAPP). The West and Central Africa Council for Agricultural Research and Development (CORAF/WECARD), Dakar, Senegal. 120p.

Styger, E., Attaher, M.A., Guindo, H., Ibrahim H., Diaty, M., Abba, I., and Traore M. (2011). Application of system of rice intensification practices in the arid environment of the Timbuktu region in Mali. *Paddy Water Environ* 9, 137–144. https://doi.org/10.1007/s10333-010-0237-z

Tàbara J, Frantzeskaki N, Hölscher K, Pedde S, Kok K, Lamperti F, Christensen JH, Jäger J, Berry P. (2018). Positive tipping points in a rapidly warming world. *Sustain Gov Transform* 2018 (31):120–129. https://doi.org/10.1016/j.cosust.2018.01.012

Termeer CJAM, Dewulf A, Biesbroek GR (2017). Transformational change: Governance interventions for climate change adaptation from a continuous change perspective. *J Environ Plan Manage* 60(4):558–576. https://doi.org/10.1080/09640568.2016.1168288

Theis, S., N. Lefore, R. Meinzen-Dick, and E. Bryan. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human Values* 35 (2018): 671–684.

Tongwane, M. I., and Moeletsi, M. E. (2018). A review of greenhouse gas emissions from the agriculture sector in Africa. *Agric. Syst*. 166, 124–134. doi:10.1016/j.agsy.2018.08.011

Turhan, N. S. (2020). Karl Pearson's Chi-Square Tests. *Educational Research and Reviews*, 16(9), 575-580.

Uphoff, N. (2012) Comment to the System of Rice Intensification: Time for an empirical turn, *NJAS-Wageningen Journal of Life Sciences*, 57, 217-224. doi:10.1016/j.agsy.2009.01.001

Uphoff, N. (2009). The System of Rice Intensification (SRI) as a System of Agricultural Innovation. Paper for Institute of Development Studies conference, Sussex, UK, 2009. http://repository.ipb.ac.id/handle/123456789/43778

Uphoff, N. (2016). The System of Rice Intensification (SRI)-Responses to frequently asked question. SRI-Rice, B75 Mann Library, Cornell University, Ithaca, New York 14853, USA

van Oort P. A. J., Zwart S. J. (2017). Impacts of climate change on rice production in Africa and causes of simulated yield changes. *Glob Chang Biol*. 24(3):1029-1045. doi:10.1111/gcb.13967.

Veeramani, P., Durai Singh R. and Subrahmaniyan K. (2012). Study of phyllochron - System of Rice Intensification (SRI) technique. *Agricultural Science Research Journals* Vol. 2(6) pp. 329 – 334, June 2012, ISSN-L: 2026-6073

Vengatesan, K. & Bhaskar Ranjana, Mahajan & Padmanaban, Sanjeevikumar & Mangrule, R. & Kala, Viswanath & Pragadeeswaran,. (2018). Performance Analysis of Gene Expression Data Using Mann–Whitney U Test. 10.1007/978-981-10-4762-6_67.

Vetter, S. H., Malin, D., and Smith, Hillier, J. (2018). The potential to reduce GHG emissions in egg production using a GHG calculator–A Cool Farm Tool case study. J. Cleaner Prod. 202, 1068–1076. doi:10.1016/j.jclepro.2018.08.199

Wayal, Dipak. (2016). An Application of Mann-Whitney U Test for Language Proficiency Assessment.

Whatley, M. (2022). One-Way ANOVA and the Chi-Square Test of Independence. In: Introduction to Quantitative Analysis for International Educators. Springer Texts in Education. Springer, Cham. https://doi.org/10.1007/978-3-030-93831-4_5

WWF-ICRISAT (2010) More rice for people, more water for the planet. WWF-ICRISAT, Hyderabad.

Zhao, L., Wu, L, Li, Y., Lu, X., Zhu, D. and Uphoff, N. (2009) Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates. *Experimental Agriculture*, 45, 275-286. doi:10.1017/S0014479709007583

ANNEXES

Annex I: Questionnaire

****

Localité ……..

Date ……

1. Caractéristiques de l'exploitant et de l'exploitation

1.1 Nom de la personne enquêtée (le décideur des activités dans l'exploitation)

Prénoms ……..…..……Nom……..……..……

1.2 Contact :……1.3 Village :…….....

1.4 Age ……1.5 Genre : Homme / Femme

1.6 Quel est votre niveau d'instruction ?.....

1.7 Combien de personnes avez-vous dans votre ménage ?.....

1.8 Combien de personnes avez-vous pour vos activités de production rizicoles ?.....

Hommes :……Femmes :……Enfants (moins de 15 ans) :…..…….

1.9 Engagez-vous de la main d'œuvre externe ? Oui / Non

1.9.1 Si oui, Combien ?.....

1.9.2 Si non, pourquoi ?.....

……

1.10 Quelles sont les spéculations que vous cultivez et quelles sont leurs superficies ?

1……/……ha…2……/……ha

3……/……ha…4……/……ha

5……/……ha…6……/……ha

7……/……ha…8……/……ha

9……/…...ha…10……../……ha

1.11 Quels sont les équipements que vous possédez ?.....

……...

2. Activités, revenu et sources

2.1. Quelle est votre principale source de revenu ?

……...

2.2. Quelles sont vos activités secondaires (par ordre d'importance) ?

……...

2.3. Quel est votre revenu annuel ou par saison ?.....

3. Appartenance à une organisation paysanne et accès aux services d'encadrement

3.1 Etes-vous membre d'une organisation paysanne ? Oui / Non

3.1.1 Si oui, laquelle ?

……...

3.1.2 Si oui, quels sont les objectifs et activités de votre organisation ?

……

……

3.1.3 Si non, pourquoi ?

……...

3.2 Avez-accès aux services d'encadrement de l'Etat ? Oui / Non

3.2.1 Si oui, de quelle nature ?

……

3.2.2 Si oui, à quelle fréquence ?

……

3.2.3 Si non, pourquoi ?

……

3.3 Travaillez-vous (ou avez-vous travaillé) avec un projet ou une ONG ? Oui / Non

3.3.1 Si oui, lequel/laquelle ?

……

3.3.2 En quoi consiste (ou a consisté) cette collaboration ?

…….

…….

3.3.3 Quand est-ce qu'a eu lieu cette collaboration ?.....

……....

4. Riziculture : connaissances, pratiques et dynamiques

4.1 Quelle est la superficie totale de votre champ de riz ?.....ha

4.2 Depuis quand produisez-vous le riz ? ……..……..ha

4.3 De cette date à maintenant, les pratiques de riziculture ont-elles changé ? Oui / Non

4.4 Si oui, quels sont les changements (ou quelles sont les nouvelles pratiques introduites) ?

……..

……..

4.5 Comment expliquez-vous ces changements de pratiques ?

……

……

4.6 Avez-vous une appellation pour votre pratique ?

……

4.7 Connaissez-vous d'autres pratiques de riziculture ? Oui / Non

4.7.1 Si oui, lesquelles ? ……...

5. SRI : Connaissances, avantages, contraintes, adoption et stratégie

5.1 Connaissez-vous le SRI (si non évoqué) ? Oui / Non

5.1.1 Si oui, Qu'est-ce que le SRI ?

……

……

5.1.2 Si oui, comment avez-vous connu le SRI ?

……

……

5.2 Appliquez-vous SRI ? Oui / Non

5.2.1 Si oui, sur combien d'hectares l'appliquez-vous ? ……..……

5.2.2 Si non, pourquoi ? …….

5.3 Quels sont les principes du SRI que vous connaissez ?

……..

……..

5.4 Quels sont les principes que vous appliquez actuellement ?

……..

……..

5.5 Qu'est-ce qui motive l'application de ces principes ?

……

……

5.6 Depuis quand appliquez-vous ces principes ?.....

……

5.7 Y-a-t ’il des principes que vous appliquiez mais que vous avez délaissés par la suite ?

Oui / Non

5.7.1 Si oui, lesquels ?

……..

……..

5.7.2 Pourquoi les avez-vous délaissés ?

……..

……..

5.8 Y-a-t’il des principes que vous n’avez jamais appliqués ? Oui / Non

5.8.1 Si oui, lesquels ?

……...

……

5.8.2 Si oui, qu’est-ce qui motive la non application de ces principes ?

……

……

5.8.3 Qu’est-ce qu’il faut pour que vous puissiez appliquer ces principes ?

……

……

6. Intrants : types, accès, contraintes et utilisation

6.1 Comment accédez-vous aux semences ?

……

……

6.2 Quels types d’engrais chimiques utilisez-vous ?

……

……

6.3 Comment accédez-vous aux engrais chimiques ?

……

……

6.4 Quelle quantité appliquez-vous à l’hectare sous le SRI ?

……

……

6.5 Quelle quantité appliquez-vous à l’hectare sous votre système habituel ?

……

……

6.6 Avez-vous des difficultés d'accès à l'engrais chimique ? Oui / Non

6.6.1 Si oui, lesquelles ?.....

6.6 Utilisez-vous de l'engrais organiques ? Oui / Non

6.6.1 Si non, pourquoi ?.....

……

6.6.2 Si oui, quels types d'engrais organiques (composte et ou organique industriel) ?

……

……

6.6.3 Quelle quantité appliquez-vous à l'hectare sous le SRI ?

……

6.6.4 Quelle quantité appliquez-vous à l'hectare sous votre système habituel ?

……

6.7 Avez-vous des difficultés d'accès à l'engrais organique ? Oui / Non

6.7.1 Si oui, lesquelles ?

……

……

6.8 Avez-vous accès au crédit pour financer vos activités de production ? Oui / Non

6.8.1 Si oui, comment obtenez-vous du crédit ?

……

……

6.8.2 Si oui, combien prenez-vous par an ou par saison ?.....

……

6.8.3 Si non, pourquoi ?.....

7. Rendement et dynamique

7.1 Quel est votre rendement à l'hectare sous le SRI ?.....

7.2 Quel est votre rendement à l'hectare sous votre système habituel ?.....

8. Autres questions

8.1 Selon vous, quelles conditions faut-il réunir pour que vous puissiez appliquer l'intégralité des principes du SRI ?.....

…….

…….

8.2 Quelles autres préoccupations majeures avez-vous dans le domaine de la production rizicole ?

…….

…….

…….

…….

Annex II: Guide for the focus group discussion with producers

(Themes and sub-themes discussed)

Organization of the producers in the scheme

Relation producers-management

Irrigation

- Source of irrigation water:
- Irrigation equipment
- Irrigable area
- Irrigation problems
- Periods concerned
- Sectors/areas concerned
- Drainage problems
- Periods concerned
- Sectors/areas concerned
- Perimeter equipment for drainage (and operationality)

SRI

- Introduction
- Practice
- Advantages and constraints

Inputs management

Organization of work in the scheme

- Family workers
- External workers
- Workers groups in the scheme

General challenges

Omitted subjects that matter 1/1

Annex III: Guide for the focus group discussion with women transplanters

(Themes and sub-themes discussed)

Composition and organisation of women transplanting groups

Transplanting methods and challenges

Transplanting costs and evolution

Implication in other activities

Roles in households

Farm ownership and management

General challenges

Omitted subjects that matter

1/1

Annex IV: Staff interview guide

(Themes and sub-themes discussed)

Brief history of the irrigated scheme

All documentation on the scheme including the physical presentation (official documents, old dissertations, reports, theses)

Key figures

Total gross area

Area dedicated to rice

Other speculations and area

Number of producers: Male: Female:

Area sown: Season: Off-season:

Average yield under SRI: Season: Off-season:

Average yield without SRI: Season: Off-season:

Irrigation

- Source of irrigation water:
- Irrigation equipment
- Irrigable area
- Irrigation problems
- Periods concerned
- Sectors/areas concerned
- Drainage problems
- Periods concerned
- Sectors/areas concerned
- Perimeter equipment for drainage (and operationality)
- Length of irrigation and drainage network: (primary, secondary and tertiary)

SRI Statistics

- Year of introduction
- Application rate: Season: Off-season: 1/2

- Principles considered for estimating the rate:
- Problems reported regarding the application of the principles

Perimeter management:

- Framework of the State-OPIB-Producers relationship:
- Roles and responsibilities of the State:
- Roles and responsibilities of the OPIB:
- Roles and responsibilities of producers:

Inputs management

Decision-makers in rural activities

Geographical location of producers in the area (villages)

Village selection criteria

List of villages and contact persons

Interactions with producers and their groups: facilities, constraints, perspectives

General challenges

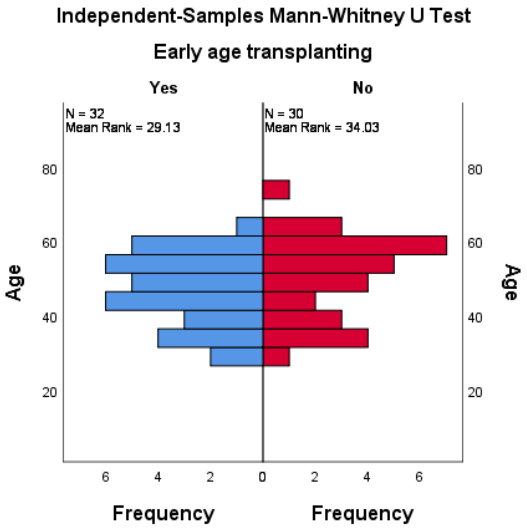
Omitted subjects that matter

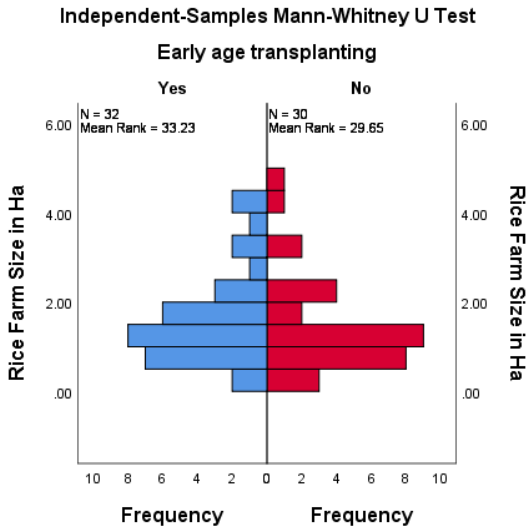
Annex V: Full Analyses report Chi-square and Mann-Whitney U tests for different principles

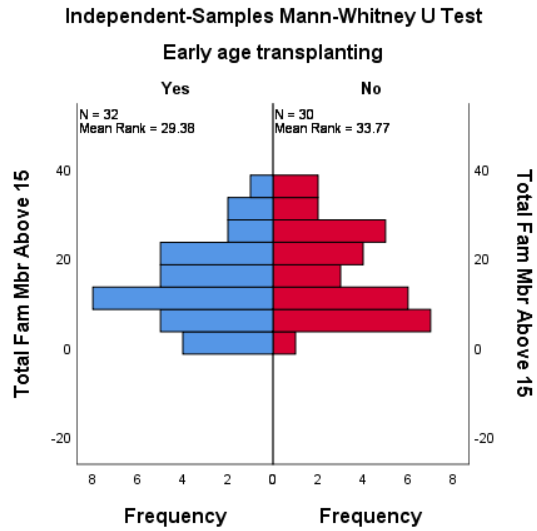
Annex V-a: Early Age Transplanting

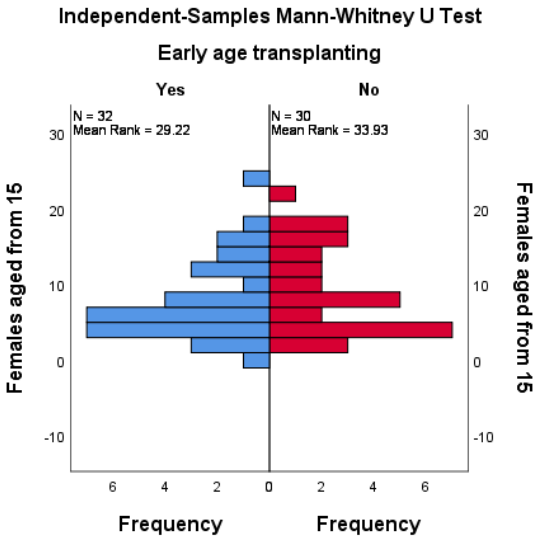
Chi-Square Tests Results Early Age Transplanting							
Factors	Chi-Square value	Continuity correction	Significance	Significance continuity correction	Df	Phi	Cramer's V
Education level (formal)	9.46		0.05		4.00	0.39	0.39
Worker engagement frequency	0.66		0.88		3.00	0.10	0.88
External worker engagement	0.52	0.20	0.47	0.66	1.00	0.09	0.09
Gender	3.36	1.54	0.07	0.21	1.00	0.23	0.23
Membership of a FBO	0.53	0.19	0.46	0.66	1.00	0.09	0.09
Access to government advisory service freq	7.16		0.07		3.00	0.34	0.34
Access to government advisory service	4.22	3.00	0.04	0.08	1.00	0.26	0.26
Access to project NGO assistance	7.75	6.39	0.01	0.01	1.00	0.35	0.35
How did you know the SRI	5.47		0.06		2.00	0.30	0.30
Easy irrigation	2.89	1.79	0.09	0.18	1.00	-0.22	0.22
Easy drainage	4.07	3.10	0.04	0.08	1.00	0.26	0.26
Inundation	6.53		0.04		2.00	0.32	0.32
Difficulty to access chemical fertiliser	1.94	0.45	0.16	0.50	1.00	-0.18	0.18
Difficulty to access organic fertiliser	1.03	0.58	0.31	0.45	1.00	-0.13	0.13
Loan taking	3.75	2.79	0.05	0.09	1.00	-0.25	0.25
Where or who do you take loan from	7.65	8.62	0.11	0.07	4.00	0.35	0.35

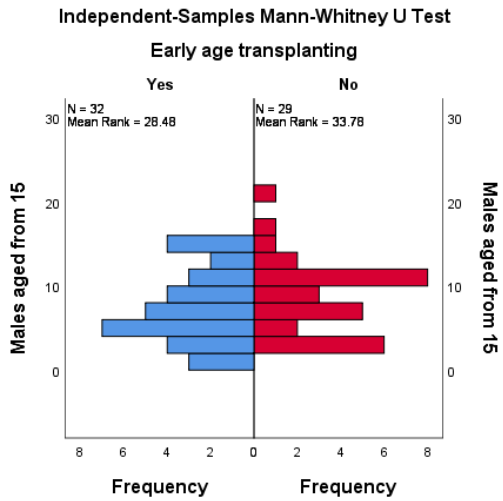
Mann-Whitney U results / Early Age Transplanting							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	556.00	1.07	0.28	29.13	34.03	49.50	52.00
Size of the household	551.00	1.00	0.32	29.28	33.87	22.50	27.50
Total number of workers in the household	551.00	0.26	0.79	30.44	31.62	5.50	6.00
Males above fifteen years old	544.50	1.17	0.24	28.48	33.78	6.00	9.00
Females above fifteen years old	553.00	1.03	0.30	29.22	33.93	6.00	8.00
Household members above fifteen years old	548.00	0.96	0.34	29.38	33.77	12.50	15.50
Size of the rice farm	424.50	-0.78	0.43	33.23	29.65	1.31	1.00
Total farm land	583.00	1.45	0.15	28.28	34.93	4.77	4.79
Transport equipment score	432.50	-0.68	0.50	32.98	29.92	2.50	3.00
Land preparation equipment score	442.00	-0.67	0.50	32.69	30.23	0.00	0.00
Total score for all equipment	444.50	-0.50	0.62	32.61	30.32	13.10	11.30
Experience in rice production	507.00	0.38	0.70	30.66	32.40	28.50	30.00
Experience in SRI application	278.50	-2.59	0.01	36.22	24.78	5.00	3.50
Amount of the loan	197.50	0.05	0.96	20.38	20.59	200000	200000

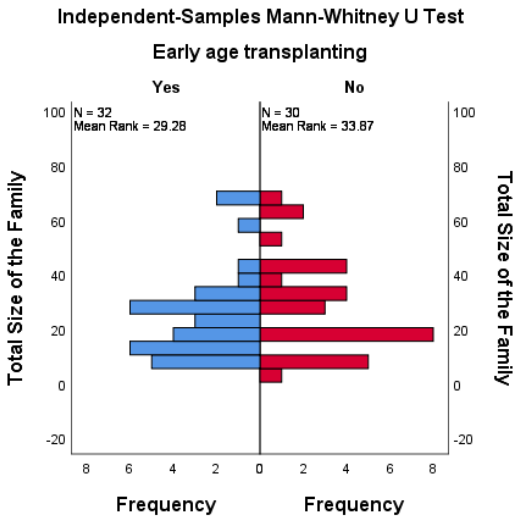

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 29.13
N = 30
Mean Rank = 34.03
Age
Frequency
Frequency

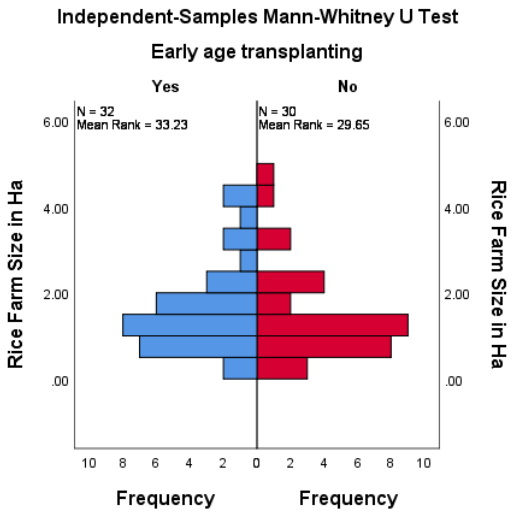

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 33.23
N = 30
Mean Rank = 29.65
Rice Farm Size in Ha
Frequency
Frequency

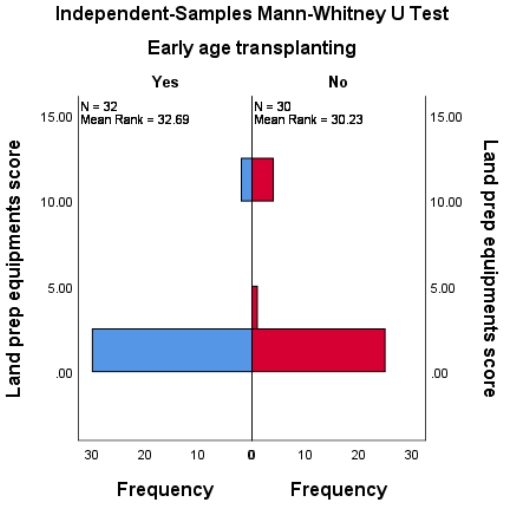

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 29.38
N = 30
Mean Rank = 33.77
Total Fam Mbr Above 15
Frequency
Frequency

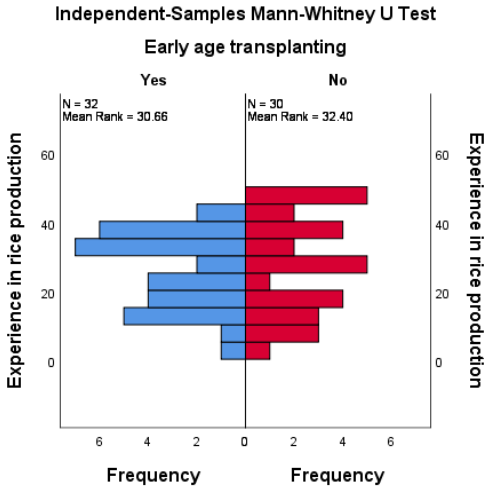

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 29.22
N = 30
Mean Rank = 33.93
Females aged from 15
Frequency
Frequency

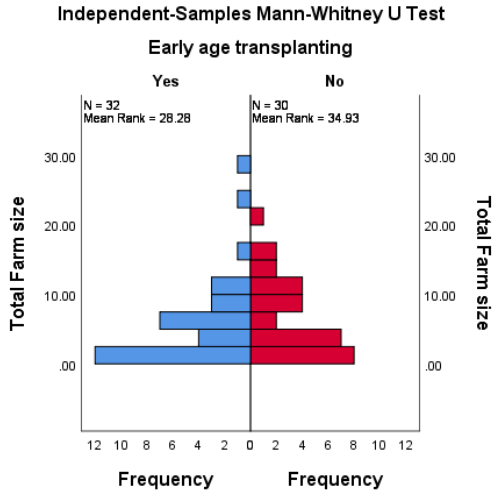

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 28.48
N = 29
Mean Rank = 33.78
Males aged from 15
Frequency
Frequency

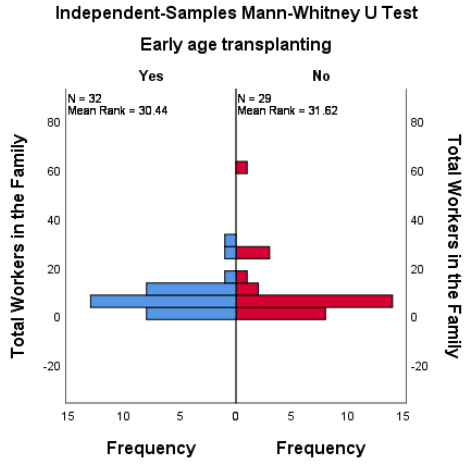

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 29.28
N = 30
Mean Rank = 33.87
Total Size of the Family
Frequency
Frequency

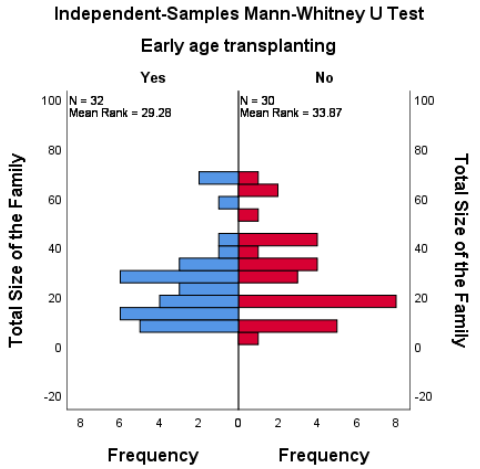

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 33.23
N = 30
Mean Rank = 29.65
Rice Farm Size in Ha
Frequency
Frequency

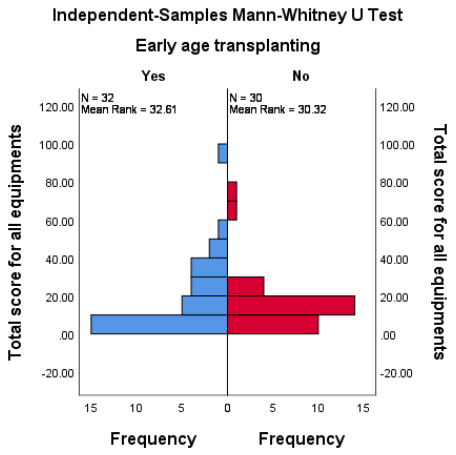

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 32.69
N = 30
Mean Rank = 30.23
Land prep equipments score
Frequency
Frequency

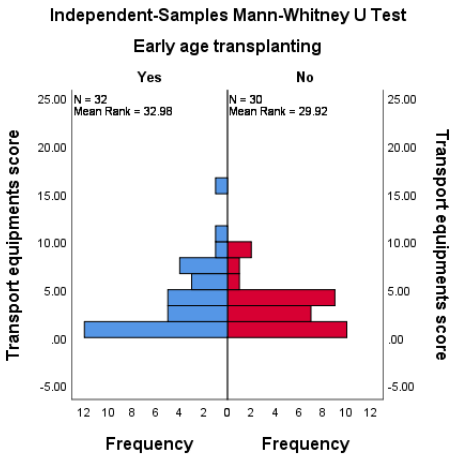

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 30.66
N = 30
Mean Rank = 32.40
Experience in rice production
Frequency
Frequency

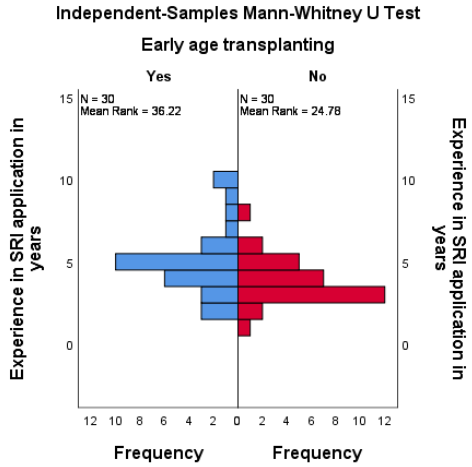

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 28.28
N = 30
Mean Rank = 34.93
Total Farm size
Frequency
Frequency

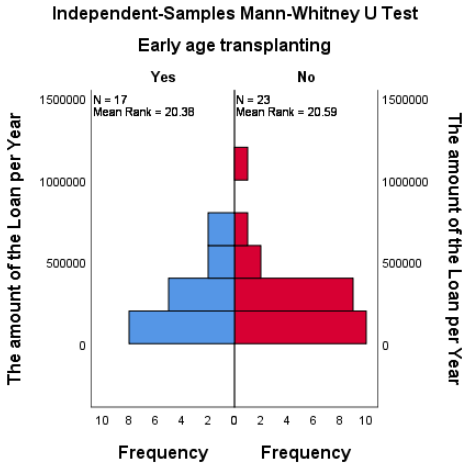

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 30.44
N = 29
Mean Rank = 31.62
Total Workers in the Family
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 29.28
N = 30
Mean Rank = 33.87
Total Size of the Family
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 32.61
N = 30
Mean Rank = 30.32
Total score for all equipments
Total score for all equipments
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 32
Mean Rank = 32.98
N = 30
Mean Rank = 29.92
Transport equipments score
Transport equipments score
Frequency
Frequency

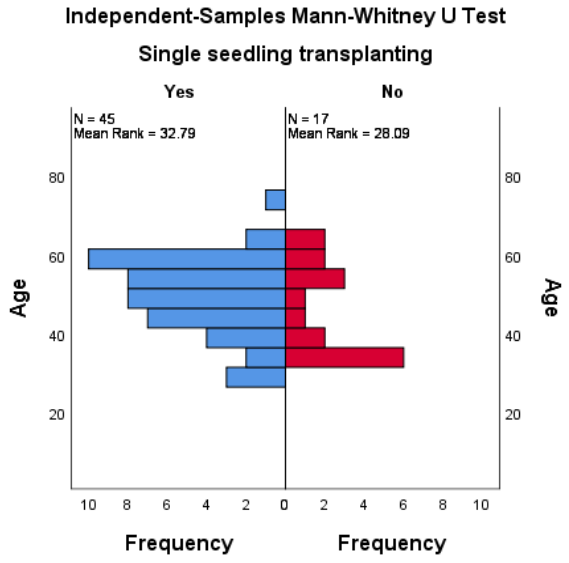

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 30
Mean Rank = 36.22
N = 30
Mean Rank = 24.78
Experience in SRI application in years
Experience in SRI application in years
Frequency
Frequency

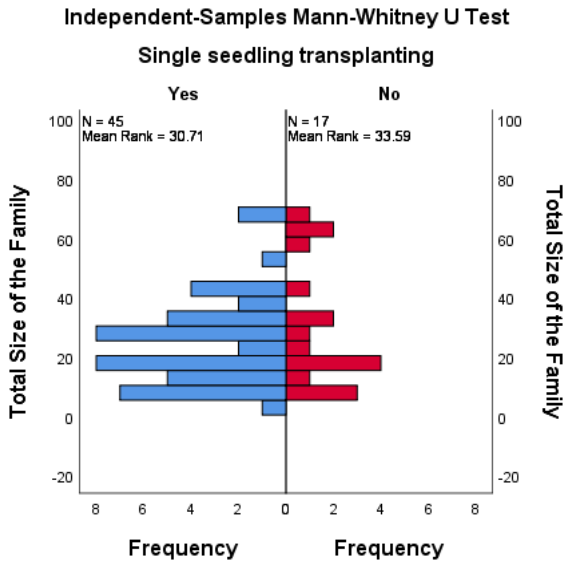

Independent-Samples Mann-Whitney U Test
Early age transplanting
Yes
No
N = 17
Mean Rank = 20.38
N = 23
Mean Rank = 20.59
The amount of the Loan per Year
The amount of the Loan per Year
Frequency
Frequency

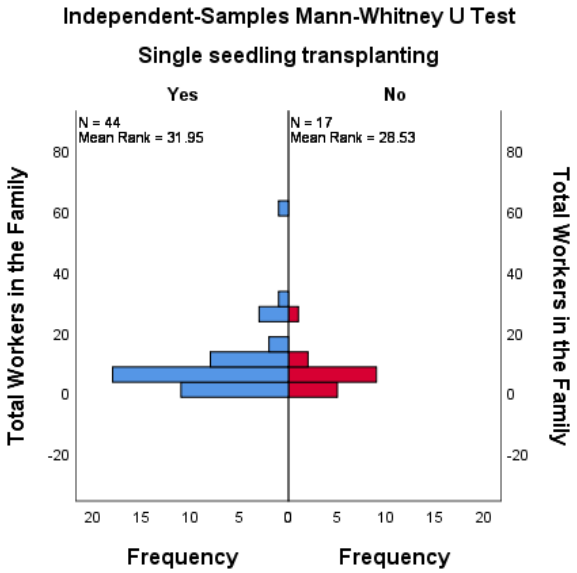
Annex V-b: Single Seedling

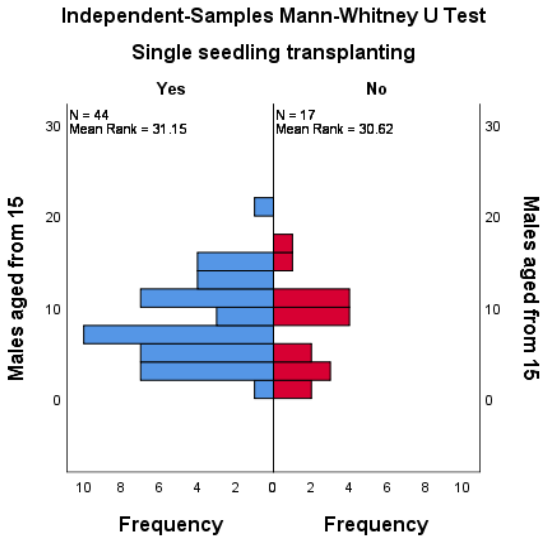
Chi-Square Tests Results Single Seedling							
Factors	Chi-Square value	Continuity correction	Significance	Significance continuity correction	Df	Phi	Cramer's V
Education level (formal)							
Worker engagement frequency							
External worker engagement							
Gender							
Membership of a FBO							
Access to government advisory service freq							
Access to government advisory service							
Access to project NGO assistance	3.61	2.61	0.06	0.11	1.00	0.24	0.24
How did you know the SRI	0.47		0.79		2.00	0.09	0.09
Easy irrigation							
Easy drainage	4.27	3.16	0.04	0.08	1.00	0.26	0.26
Inundation	8.91		0.01		2.00	0.38	0.38
Difficulty to access chemical fertiliser							
Difficulty to access organic fertiliser	0.08	0.00	0.78	1.00	1.00	-0.04	0.04
Loan taking	0.38	0.10	0.54	0.75	1.00	-0.08	0.08
Where or who do you take loan from							

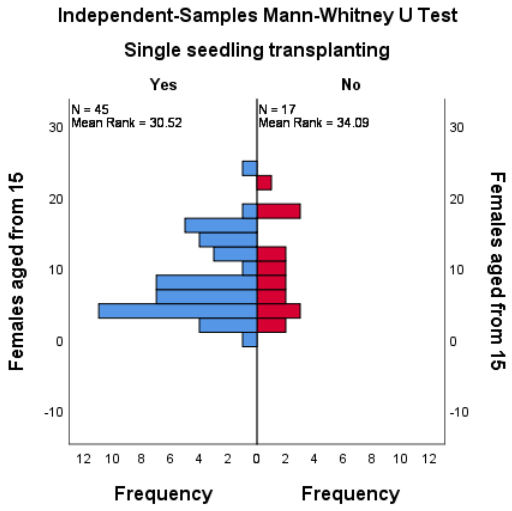
Mann-Whitney U results / Single Seedling							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	324.50	-0.92	0.36	32.79	28.09	51.00	42.00
Size of the household	418.00	0.56	0.58	30.71	33.59	23.00	25.00
Total number of workers in the household	332.00	-0.68	0.50	31.95	28.53	6.00	5.00
Males above fifteen years old	367.50	-0.10	0.92	31.15	28.53	6.00	8.00
Females above fifteen years old	426.50	0.70	0.49	30.52	34.09	6.00	8.00
Household members above fifteen years old	410.50	0.44	0.66	30.88	33.15	13.00	15.00
Size of the rice farm	424.50	0.66	0.51	30.57	33.97	1.10	1.50
Total farm land	487.00	1.65	0.10	29.18	37.65	4.49	8.25
Transport equipment score	468.00	1.36	0.17	29.60	36.53	3.00	4.00
Land preparation equipment score	415.00	0.64	0.52	30.78	33.41	0.00	0.00
Total score for all equipment	435.50	0.84	0.40	30.32	34.62	10.80	15.40
Experience in rice production	344.50	-0.60	0.55	32.34	29.26	32.00	25.00
Experience in SRI application	195.00	-2.68	0.01	34.07	20.69	4.50	3.00
Amount of the loan	166.50	-0.04	0.96	20.55	20.38	200000	165000

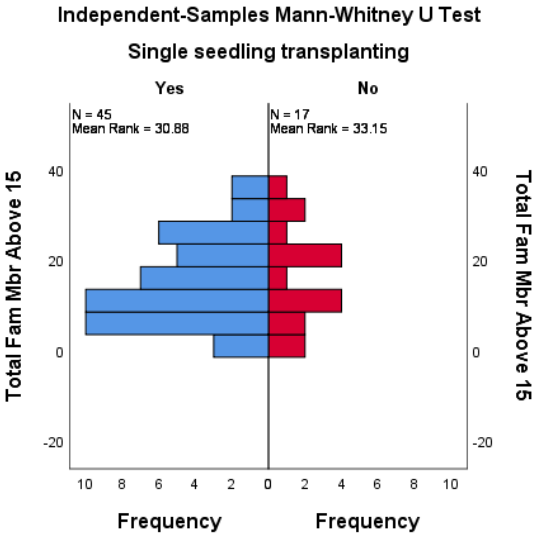

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 32.79
N = 17
Mean Rank = 28.09
Age
Frequency
Frequency

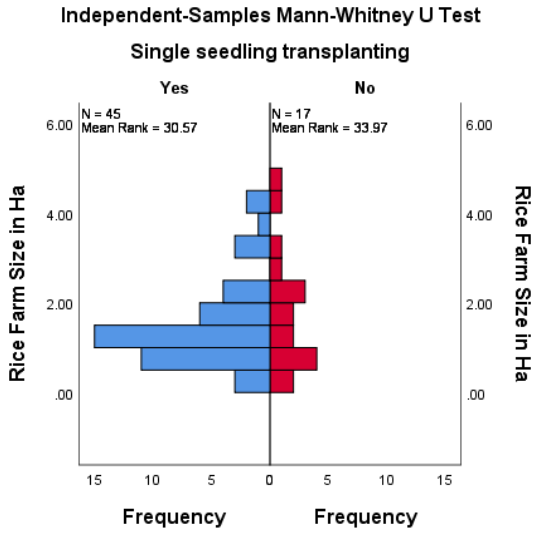

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.71
N = 17
Mean Rank = 33.59
Total Size of the Family
Frequency
Frequency

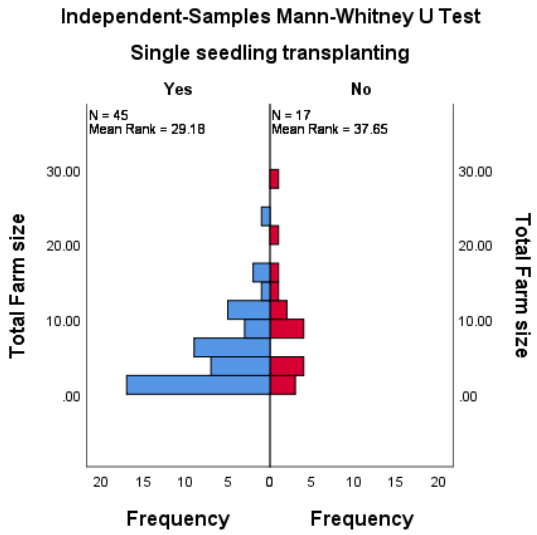

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 44
Mean Rank = 31.95
N = 17
Mean Rank = 28.53
Total Workers in the Family
Frequency
Frequency

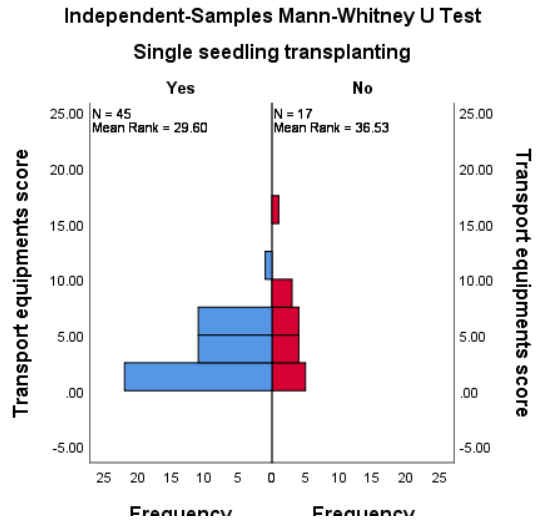

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 44
Mean Rank = 31.15
N = 17
Mean Rank = 30.62
Males aged from 15
Frequency
Frequency

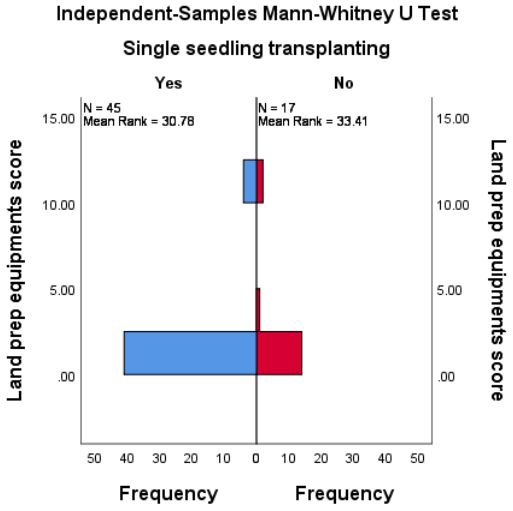

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.52
N = 17
Mean Rank = 34.09
Females aged from 15
Frequency
Frequency

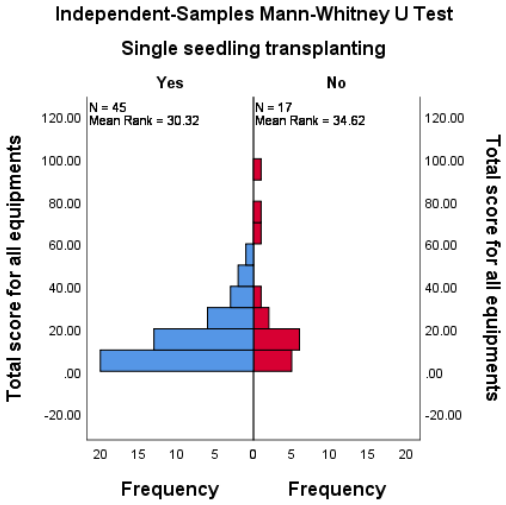

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.88
N = 17
Mean Rank = 33.15
Total Fam Mbr Above 15
Frequency
Frequency

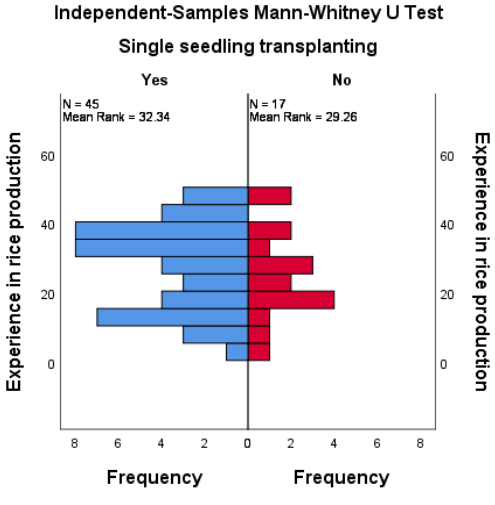

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.57
N = 17
Mean Rank = 33.97
Rice Farm Size in Ha
Frequency
Frequency

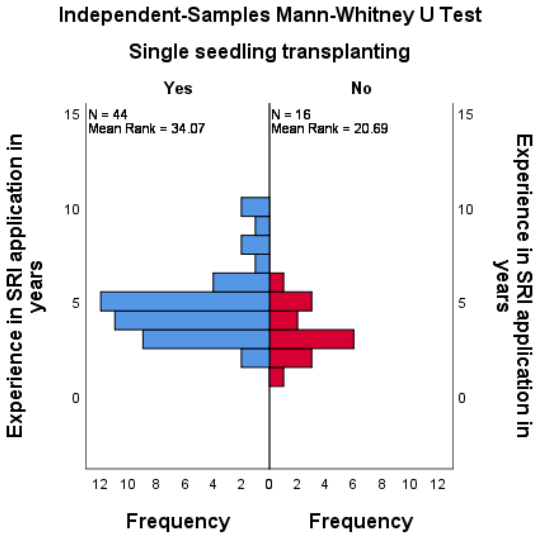

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 29.18
N = 17
Mean Rank = 37.65
Total Farm size
Frequency
Frequency

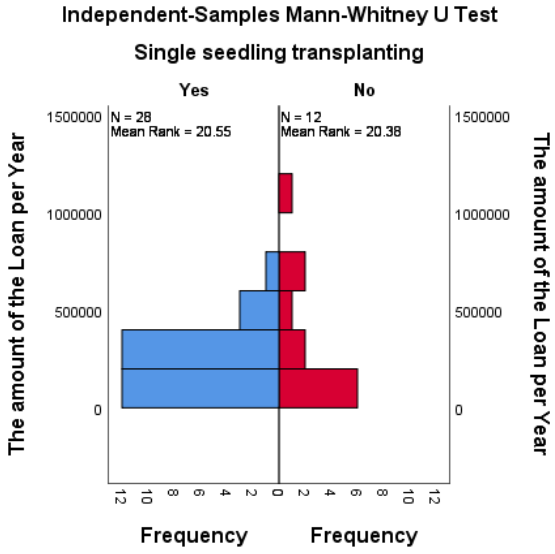

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 29.60
N = 17
Mean Rank = 36.53
Transport equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.78
N = 17
Mean Rank = 33.41
Land prep equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 30.32
N = 17
Mean Rank = 34.62
Total score for all equipments
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 45
Mean Rank = 32.34
N = 17
Mean Rank = 29.26
Experience in rice production
Frequency
Frequency

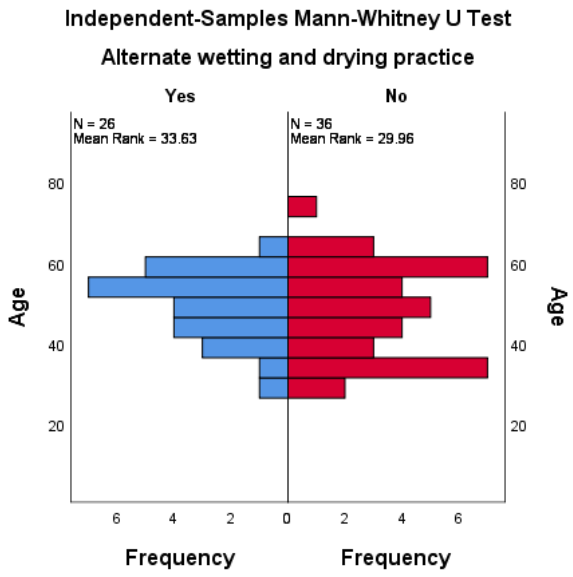

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 44
Mean Rank = 34.07
N = 16
Mean Rank = 20.69
Experience in SRI application in years
Frequency
Frequency

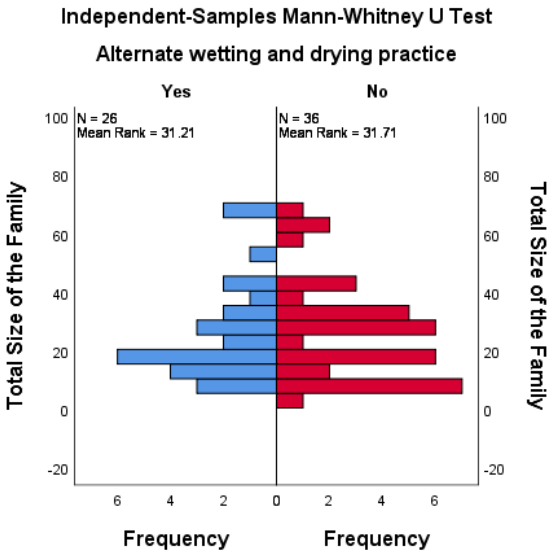

Independent-Samples Mann-Whitney U Test
Single seedling transplanting
Yes
No
N = 28
Mean Rank = 20.55
N = 12
Mean Rank = 20.38
The amount of the Loan per Year
Frequency
Frequency

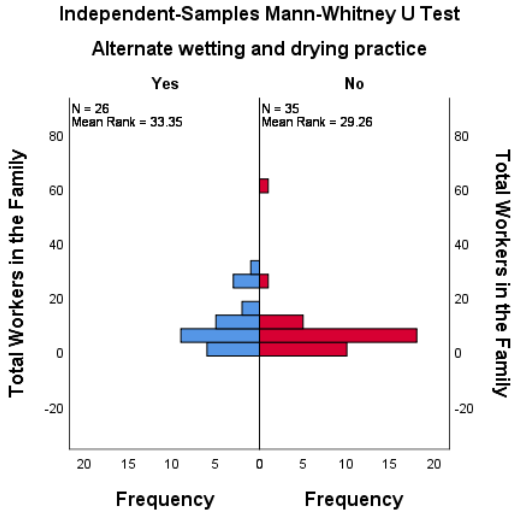
Annex V-c: Alternate Wetting and drying

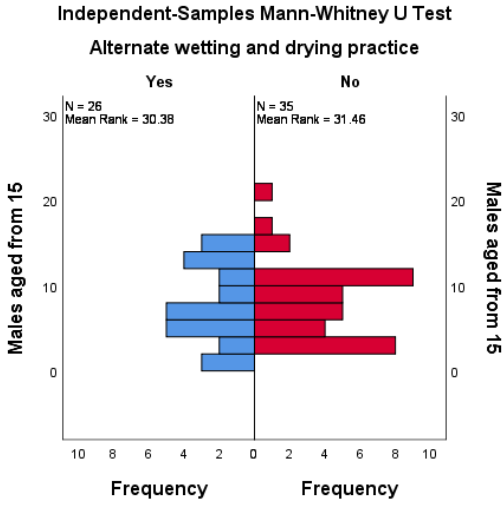
Chi-Square Tests Results Alternate Wetting and Drying							
Factors	Chi-Square value	Continuity correction	Significance	Significance continuity correction	Df	Phi	Cramer's V
Education level (formal)							
Worker engagement frequency	3.43		0.33		3.00	0.24	0.24
External worker engagement	0.77	0.35	0.38	0.55	1.00	0.11	0.11
Gender							
Membership of a FBO	0.03	0.00	0.86	1.00	1.00	-0.02	0.02
Access to government advisory service freq							
Access to government advisory service	10.75	8.72	0.00	0.00	1.00	0.42	0.42
Access to project NGO assistance	2.01	1.34	0.16	0.25	1.00	0.18	0.18
How did you know the SRI	9.69		0.01		2.00	0.40	0.40
Easy irrigation	7.60	5.72	0.01	0.02	1.00	0.35	0.35
Easy drainage	5.03	3.94	0.02	0.05	1.00	0.28	0.28
Inundation	11.27		0.00		2.00	0.43	0.43
Difficulty to access chemical fertiliser							
Difficulty to access organic fertiliser	1.06	0.60	0.30	0.44	1.00	-0.13	0.13
Loan taking	0.91	0.47	0.34	0.49	1.00	-0.12	0.12
Where or who do you take loan from							

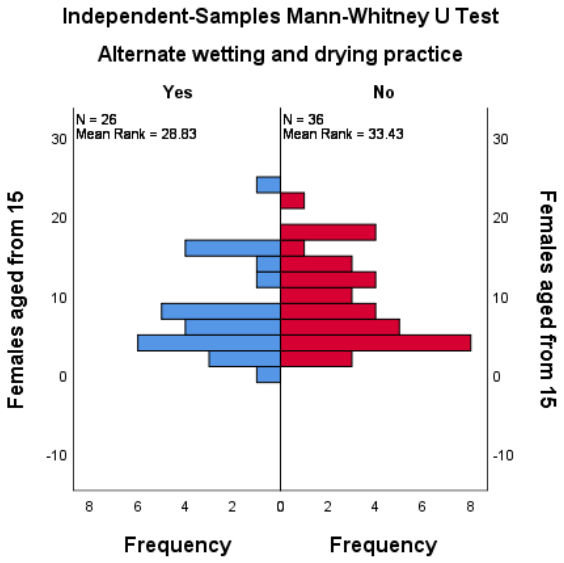
Mann-Whitney U results / Alternate Wetting and Drying							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	412.50	-0.79	0.43	33.63	29.96	51.50	48.00
Size of the household	475.50	0.11	0.91	31.21	31.71	21.00	26.00
Total number of workers in the household	394.00	-0.89	0.37	33.35	29.26	6.00	6.00
Males above fifteen years old	471.00	0.23	0.81	30.38	31.46	6.00	8.00
Females above fifteen years old	537.50	0.99	0.32	28.83	33.43	6.00	7.50
Household members above fifteen years old	509.00	0.59	0.56	29.92	32.64	12.50	15.50
Size of the rice farm	373.00	-1.36	0.17	35.15	28.86	1.43	1.00
Total farm land	574.50	1.52	0.13	27.40	34.46	4.19	6.50
Transport equipment score	480.00	0.17	0.86	31.04	31.83	2.00	3.00
Land preparation equipment score	454.00	-0.25	0.80	32.04	31.11	0.00	0.00
Total score for all equipment	446.50	-0.31	0.76	32.33	30.90	9.60	13.10
Experience in rice production	383.50	-1.21	0.23	34.75	29.15	31.00	28.50
Experience in SRI application	295.50	-2.23	0.03	36.13	26.19	5.00	3.50
Amount of the loan	148.00	-1.11	0.27	23.13	18.92	250000	150000

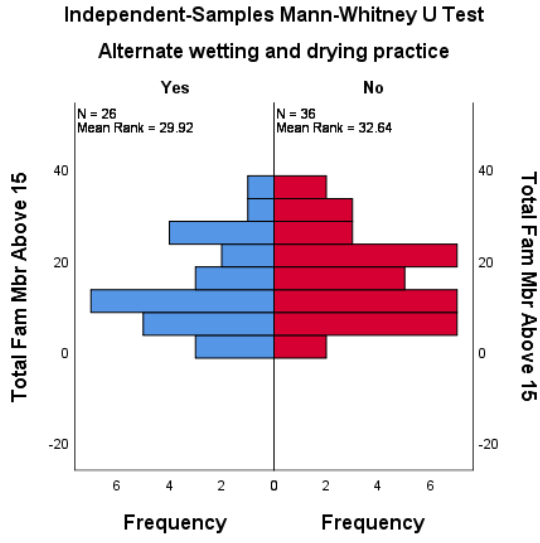

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 33.63
N = 36
Mean Rank = 29.96
Age
Frequency

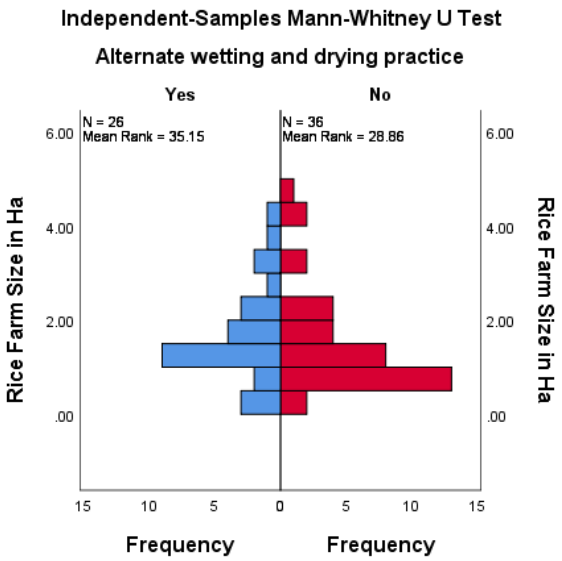

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 31.21
N = 36
Mean Rank = 31.71
Total Size of the Family
Frequency

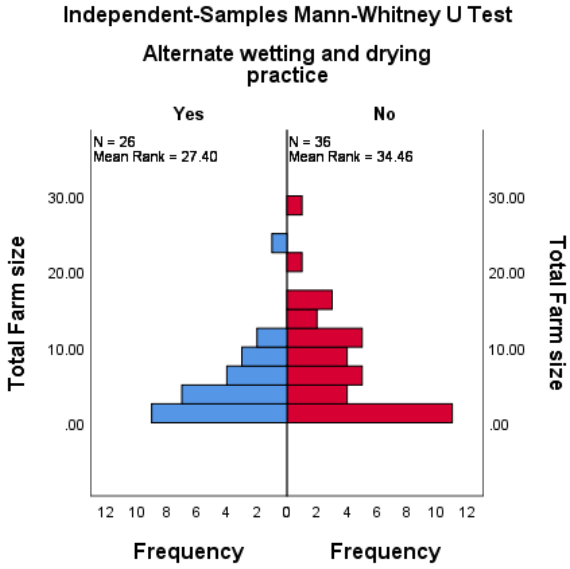

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 33.35
N = 35
Mean Rank = 29.26
Total Workers in the Family
Frequency

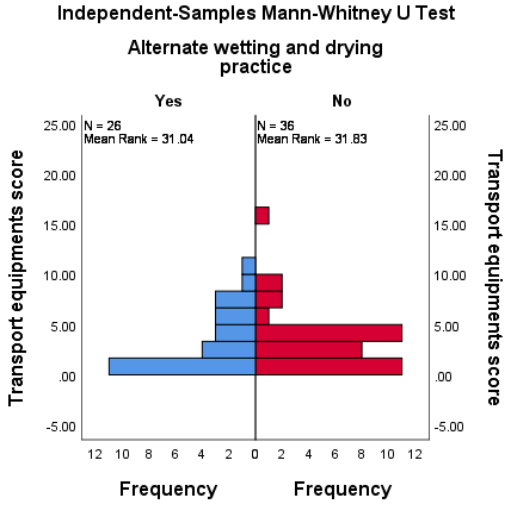

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 30.38
N = 35
Mean Rank = 31.46
Males aged from 15
Frequency

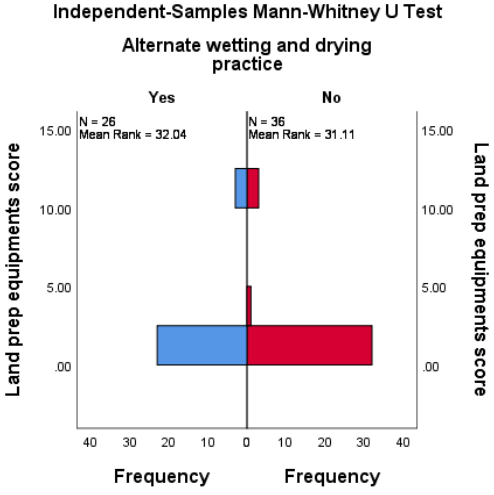

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 28.83
N = 36
Mean Rank = 33.43
Females aged from 15
Frequency

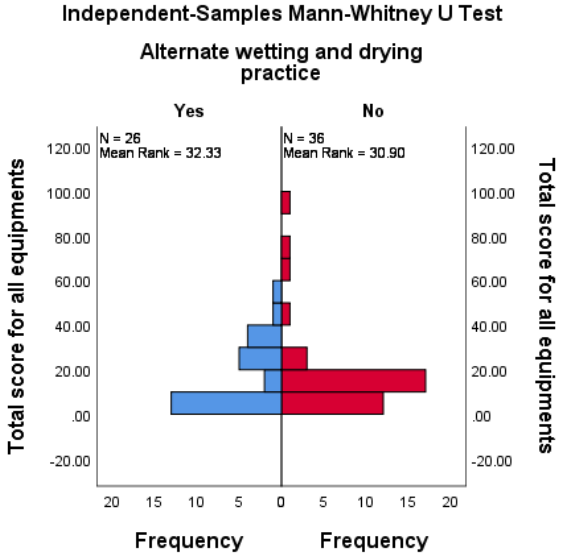

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 29.92
N = 36
Mean Rank = 32.64
Total Fam Mbr Above 15
Frequency

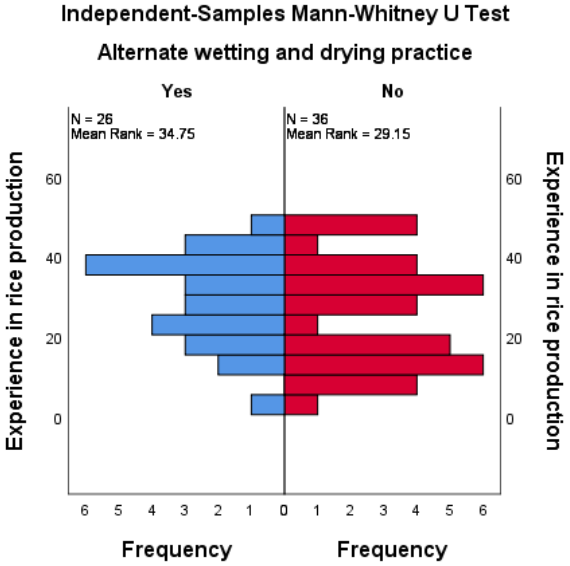

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 35.15
N = 36
Mean Rank = 28.86
Rice Farm Size in Ha
Frequency
Frequency

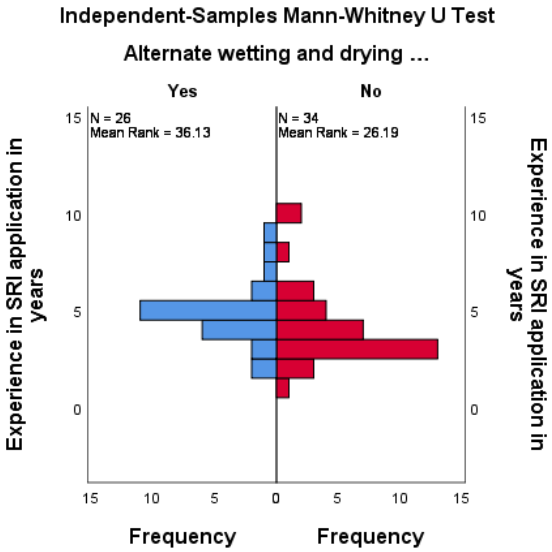

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 27.40
N = 36
Mean Rank = 34.46
Total Farm size
Frequency
Frequency

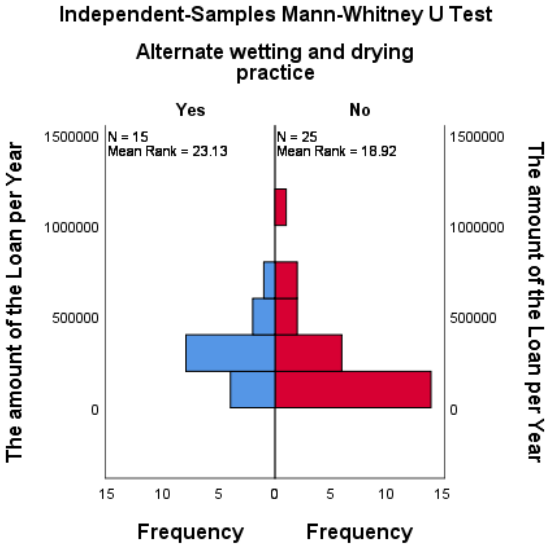

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 31.04
N = 36
Mean Rank = 31.83
Transport equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 32.04
N = 36
Mean Rank = 31.11
Land prep equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 32.33
N = 36
Mean Rank = 30.90
Total score for all equipments
Frequency
Frequency

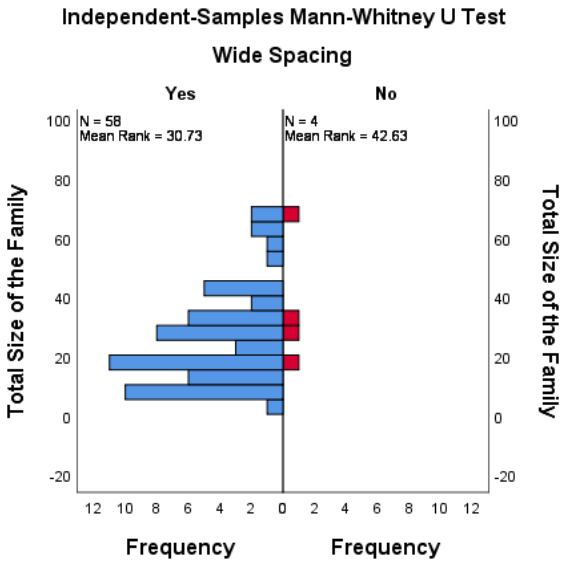

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 26
Mean Rank = 34.75
N = 36
Mean Rank = 29.15
Experience in rice production
Frequency
Frequency

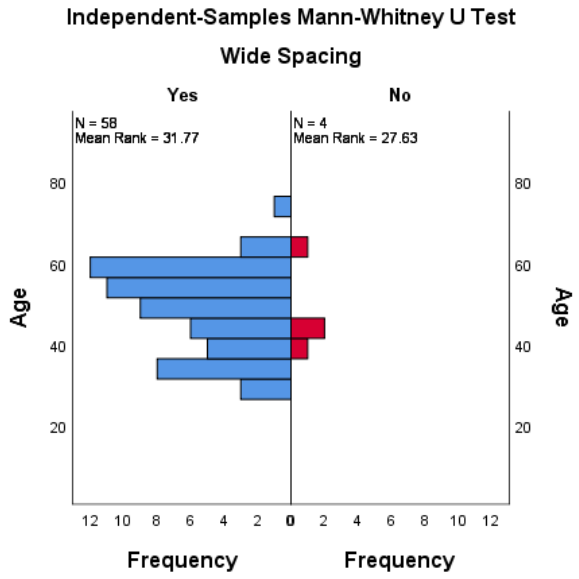

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying ...
Yes
No
N = 26
Mean Rank = 36.13
N = 34
Mean Rank = 26.19
Experience in SRI application in years
Experience in SRI application in years
15
10
5
0
Frequency
Frequency

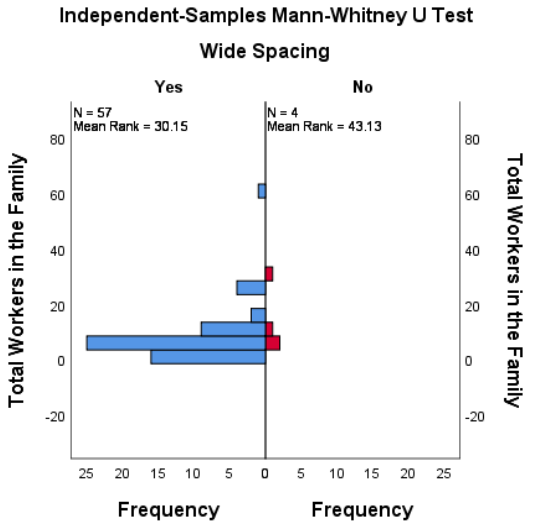

Independent-Samples Mann-Whitney U Test
Alternate wetting and drying practice
Yes
No
N = 15
Mean Rank = 23.13
N = 25
Mean Rank = 18.92
The amount of the Loan per Year
The amount of the Loan per Year
1500000
1000000
500000
0
Frequency
Frequency

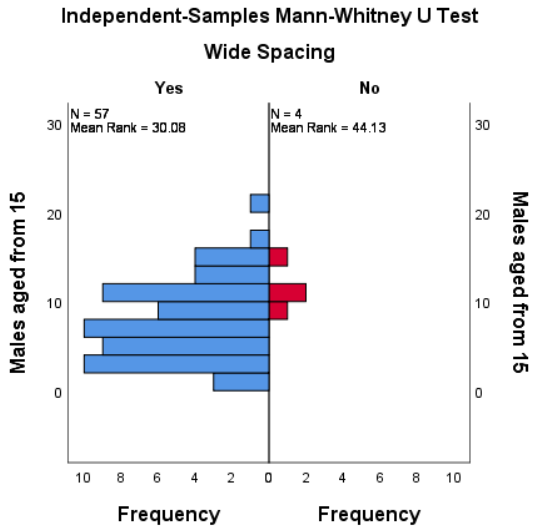
Annex V-d: Wide Spacing

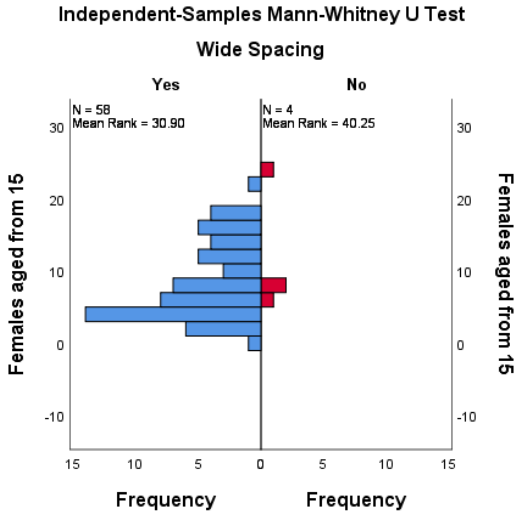
Mann-Whitney U results / Wide Spacing							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	100.50	-0.44	0.66	31.77	27.63	50.50	42.00
Size of the household	160.50	1.28	0.20	30.73	42.63	22.50	31.50
Total number of workers in the household	162.50	1.42	0.16	30.15	43.13	5.00	8.00
Males above fifteen years old	166.50	1.54	0.12	30.08	44.13	6.00	10.00
Females above fifteen years old	151.00	1.01	0.31	30.90	40.25	6.50	8.00
Household members above fifteen years old	157.50	1.19	0.23	30.78	41.88	13.00	18.00
Size of the rice farm	155.50	1.13	0.26	30.82	41.38	1.15	1.75
Total farm land	111.50	-0.13	0.90	31.58	30.38	4.79	5.95
Transport equipment score	109.50	-0.19	0.85	31.61	29.88	3.00	3.20
Land preparation equipment score	155.00	1.40	0.16	30.83	41.25	0.00	5.15
Total score for all equipment	132.50	0.47	0.64	31.22	35.63	11.80	18.65
Experience in rice production	130.50	0.42	0.68	31.25	35.13	30.00	27.00
Experience in SRI application	126.00	0.42	0.67	30.25	34.00	4.00	4.50
Amount of the loan	34.50	-0.22	0.83	20.59	18.75	200000	187500

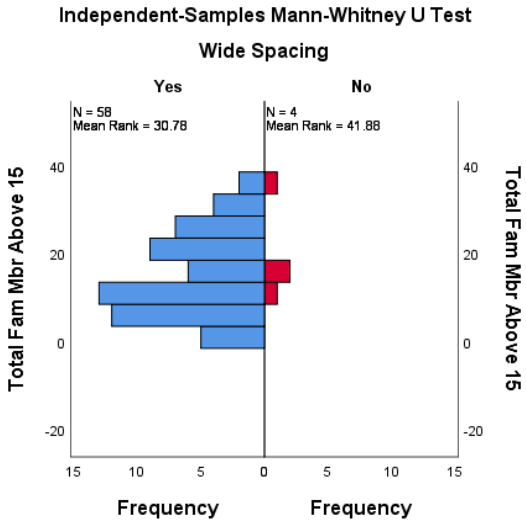

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 30.73
N = 4
Mean Rank = 42.63
Total Size of the Family
Frequency
Frequency

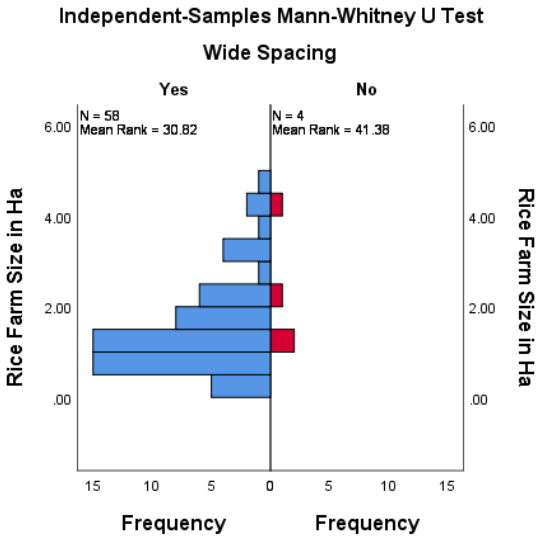

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 31.77
N = 4
Mean Rank = 27.63
Age
Frequency
Frequency

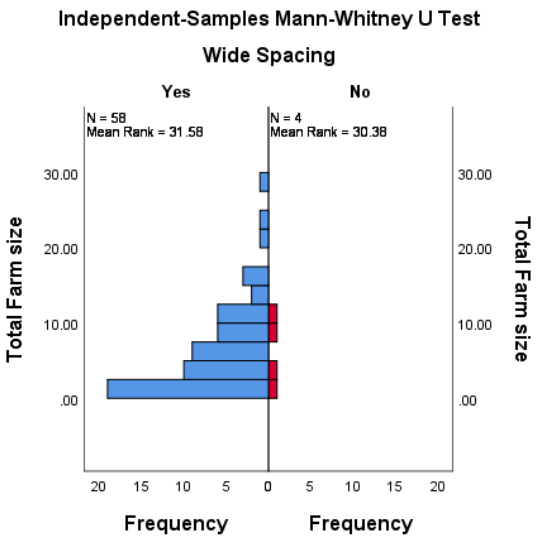

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 57
Mean Rank = 30.15
N = 4
Mean Rank = 43.13
Total Workers in the Family
Frequency
Frequency

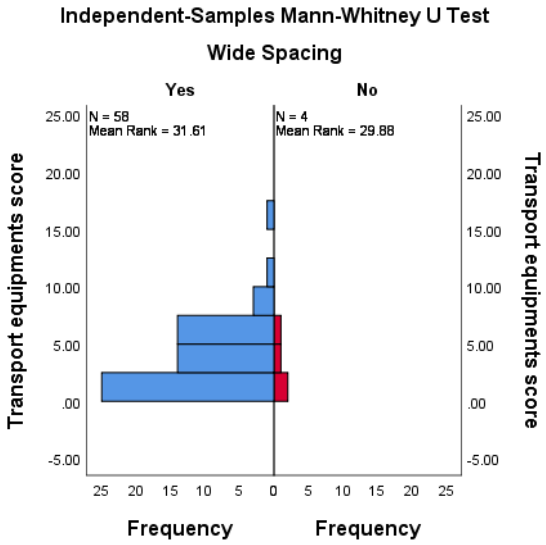

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 57
Mean Rank = 30.08
N = 4
Mean Rank = 44.13
Males aged from 15
Frequency
Frequency

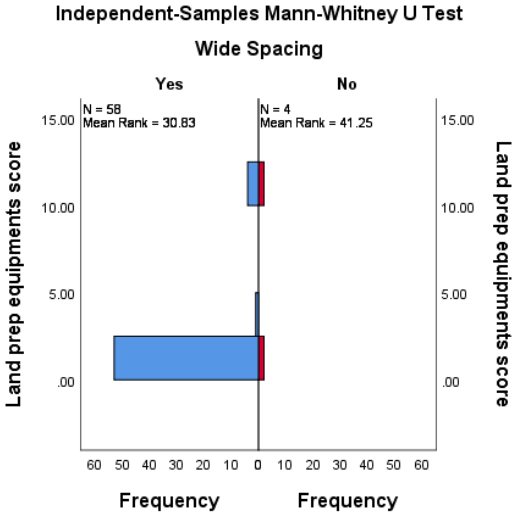

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 30.90
N = 4
Mean Rank = 40.25
Females aged from 15
Frequency
Frequency

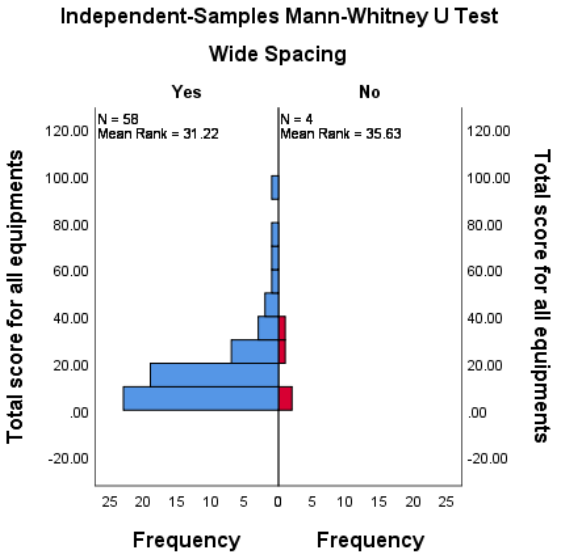

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 30.78
N = 4
Mean Rank = 41.88
Total Fam Mbr Above 15
Frequency
Frequency

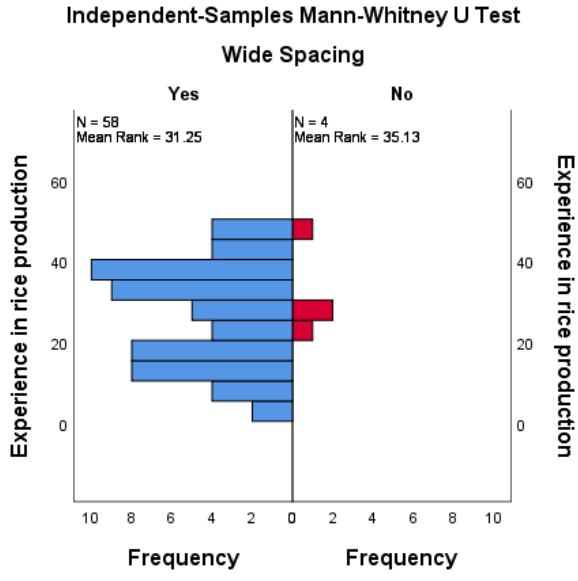

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 30.82
N = 4
Mean Rank = 41.38
Rice Farm Size in Ha
Frequency
Frequency

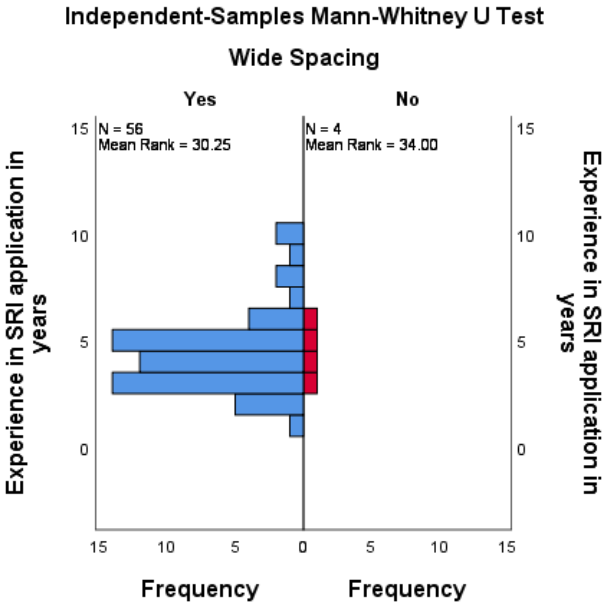

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 31.58
N = 4
Mean Rank = 30.38
Total Farm size
Frequency
Frequency

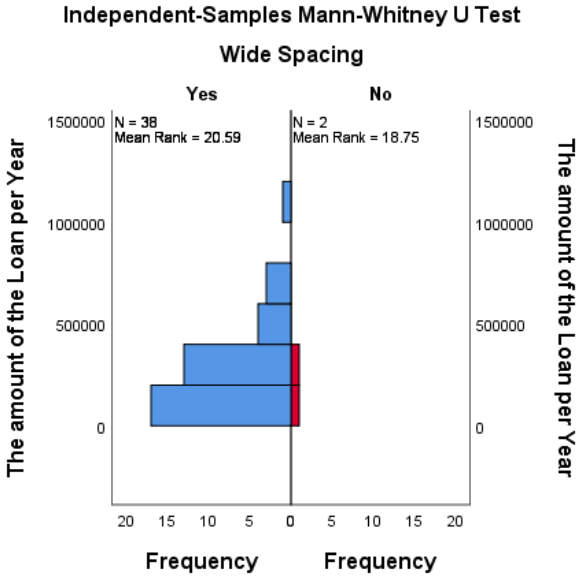

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 31.61
N = 4
Mean Rank = 29.88
Transport equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 30.83
N = 4
Mean Rank = 41.25
Land prep equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 31.22
N = 4
Mean Rank = 35.63
Total score for all equipments
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 58
Mean Rank = 31.25
N = 4
Mean Rank = 35.13
Experience in rice production
Frequency
Frequency

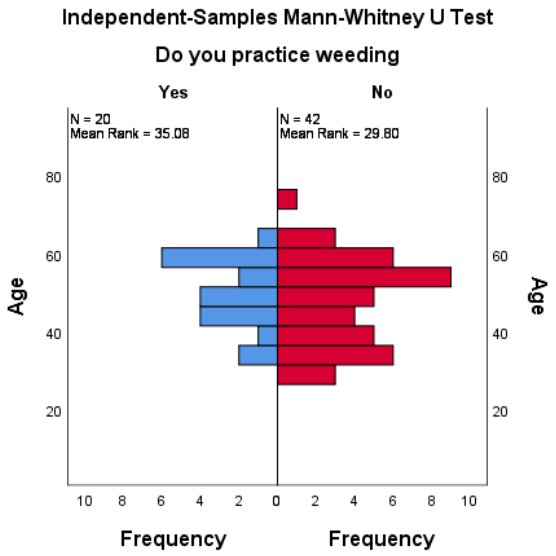

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 56
Mean Rank = 30.25
N = 4
Mean Rank = 34.00
Experience in SRI application in years
Experience in SRI application in years
15
10
5
0
Frequency
Frequency

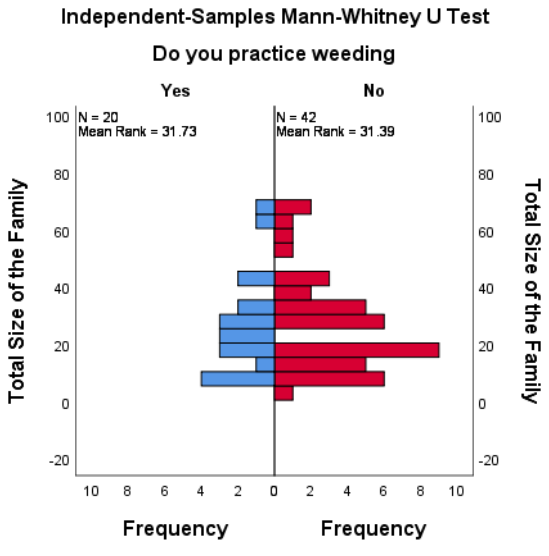

Independent-Samples Mann-Whitney U Test
Wide Spacing
Yes
No
N = 38
Mean Rank = 20.59
N = 2
Mean Rank = 18.75
The amount of the Loan per Year
The amount of the Loan per Year
1500000
1000000
500000
0
20
15
10
5
Frequency
Frequency

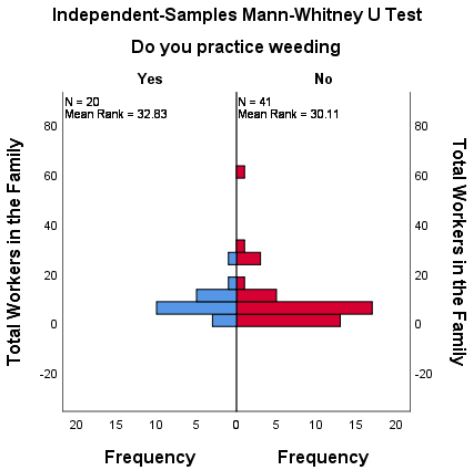
Annex V-e: Weeding

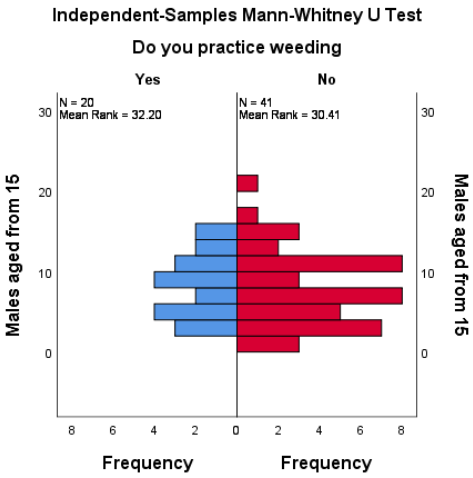
Chi-Square Tests Results Weeding							
Factors	Chi-Square value	Continuity correction	Significance	Significance continuity correction	Df	Phi	Cramer's V
Education level (formal)							
Worker engagement frequency	10.42		0.02		3.00	0.41	0.41
External worker engagement	2.82	1.91	0.09	0.17	1.00	0.21	0.21
Gender							
Membership of a FBO	0.01	0.00	0.92	1.00	1.00	0.01	0.01
Access to government advisory service freq							
Access to government advisory service	7.09	5.37	0.01	0.02	1.00	0.34	0.34
Access to project NGO assistance	1.23	0.70	0.27	0.40	1.00	0.14	0.14
How did you know the SRI	11.90		0.00		2.00	0.44	0.44
Easy irrigation							
Easy drainage	6.66	5.32	0.01	0.02	1.00	0.33	0.33
Inundation							
Difficulty to access chemical fertiliser							
Difficulty to access organic fertiliser	1.18	0.66	0.28	0.42	1.00	-0.14	0.14
Loan taking	0.00	0.00	0.96	1.00	1.00	0.01	0.01
Where or who do you take loan from							

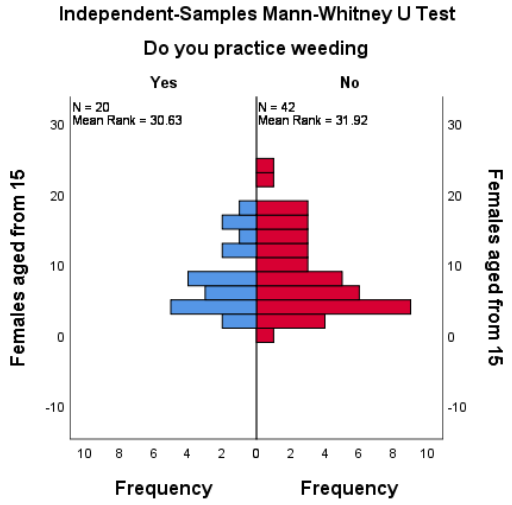
Mann-Whitney U results / Weeding							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	348.50	-1.08	0.28	35.08	29.80	50.50	49.50
Size of the household	415.50	-0.07	0.95	31.73	31.39	24.00	23.00
Total number of workers in the household	373.50	-0.56	0.57	32.83	30.11	6.00	6.00
Males above fifteen years old	386.00	-0.37	0.71	32.20	30.41	8.00	6.00
Females above fifteen years old	437.50	0.26	0.79	30.63	31.92	6.50	7.00
Household members above fifteen years old	415.50	-0.07	0.95	31.73	31.39	14.00	13.50
Size of the rice farm	379.00	-0.62	0.54	33.55	30.52	1.32	1.05
Total farm land	541.00	1.82	0.07	25.45	34.38	3.22	5.84
Transport equipment score	407.00	-0.20	0.84	32.15	31.19	2.50	3.00
Land preparation equipment score	356.00	-1.21	0.23	34.70	29.98	0.00	0.00
Total score for all equipment	389.00	-0.47	0.64	33.05	30.76	10.80	13.10
Experience in rice production	364.00	-0.84	0.40	34.30	30.17	33.00	28.50
Experience in SRI application	187.50	-3.14	0.00	41.08	25.96	5.00	4.00
Amount of the loan	85.50	-2.61	0.01	27.42	17.17	250000	150000

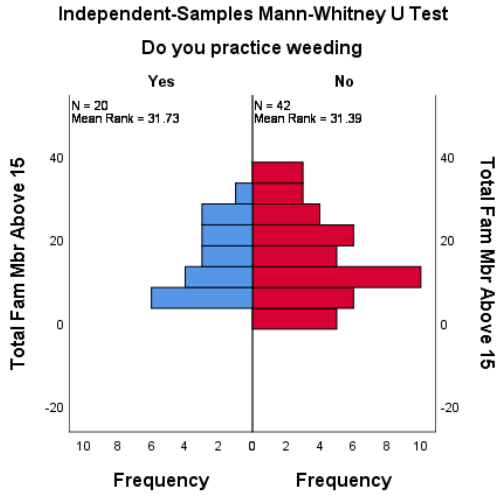

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 35.08
N = 42
Mean Rank = 29.80
Age
Frequency
Frequency

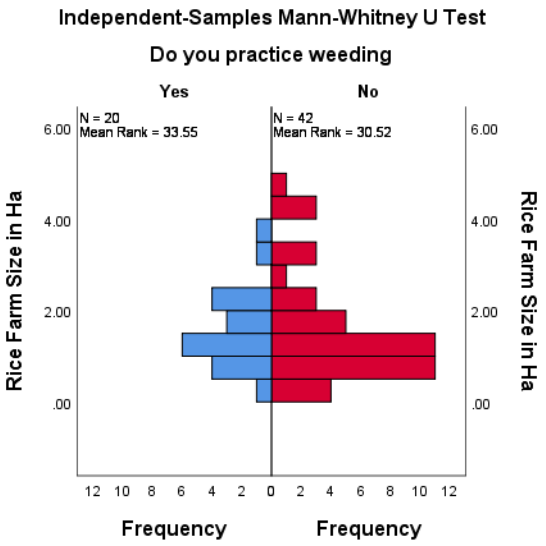

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 31.73
N = 42
Mean Rank = 31.39
Total Size of the Family
Frequency
Frequency

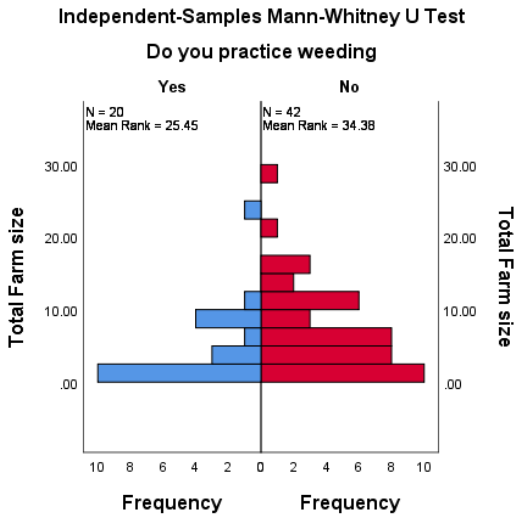

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 32.83
N = 41
Mean Rank = 30.11
Total Workers in the Family
Frequency
Frequency

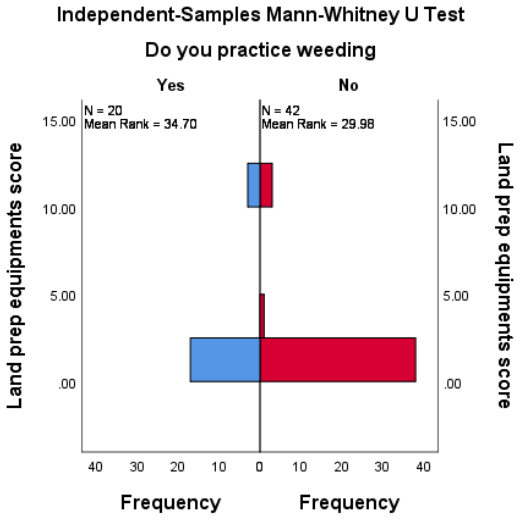

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 32.20
N = 41
Mean Rank = 30.41
Males aged from 15
Frequency
Frequency

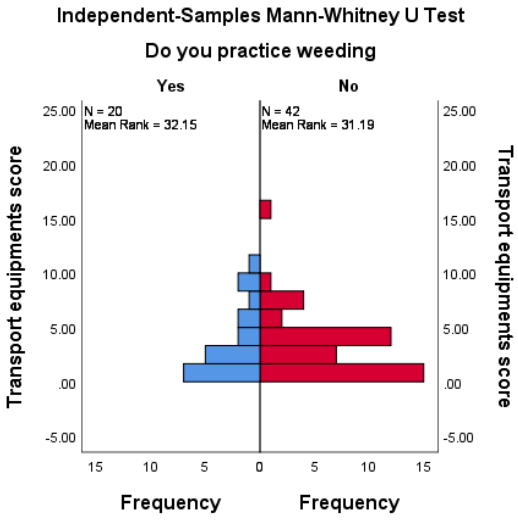

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 30.63
N = 42
Mean Rank = 31.92
Females aged from 15
Frequency
Frequency

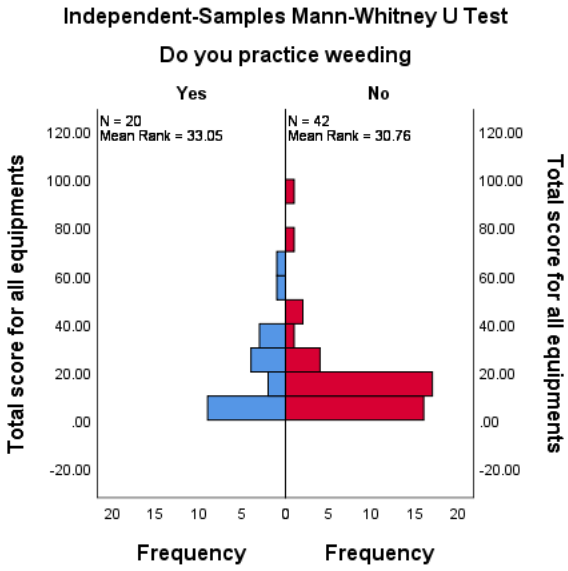

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 31.73
N = 42
Mean Rank = 31.39
Total Fam Mbr Above 15
Frequency
Frequency

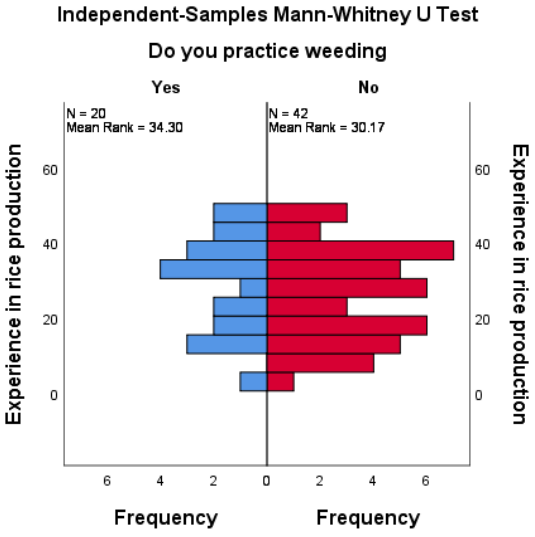

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 33.55
N = 42
Mean Rank = 30.52
Rice Farm Size in Ha
Frequency
Frequency

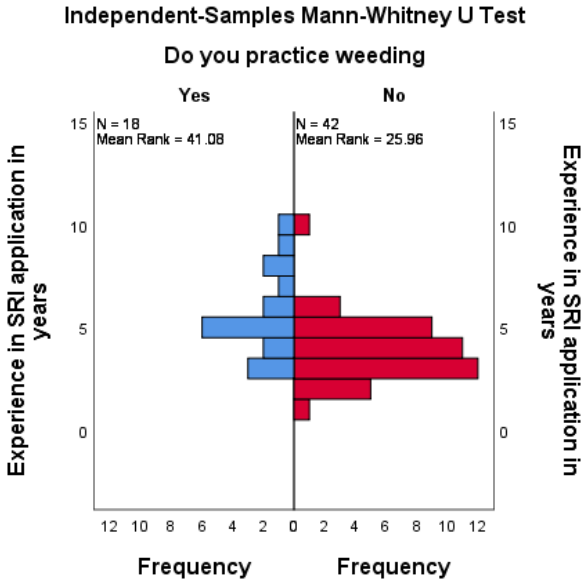

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 25.45
N = 42
Mean Rank = 34.38
Total Farm size
Frequency
Frequency

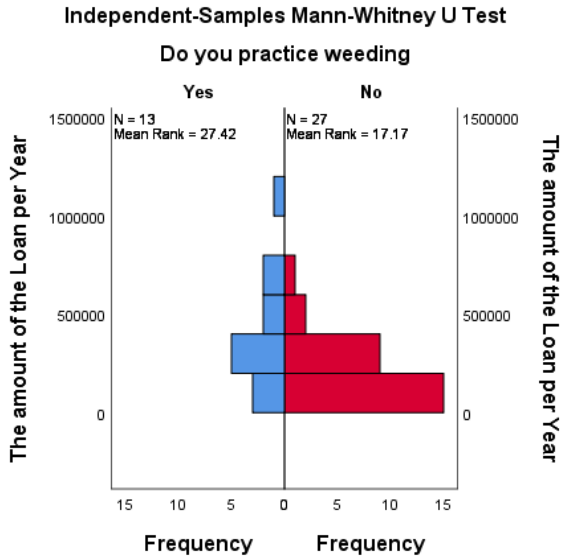

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 34.70
N = 42
Mean Rank = 29.98
Land prep equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 32.15
N = 42
Mean Rank = 31.19
Transport equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 33.05
N = 42
Mean Rank = 30.76
Total score for all equipments
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 20
Mean Rank = 34.30
N = 42
Mean Rank = 30.17
Experience in rice production
Frequency
Frequency

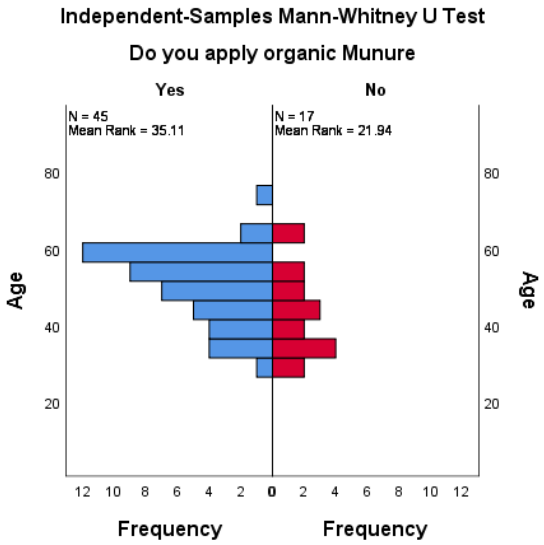

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 18
Mean Rank = 41.08
N = 42
Mean Rank = 25.96
Experience in SRI application in years
Experience in SRI application in years
Frequency
Frequency

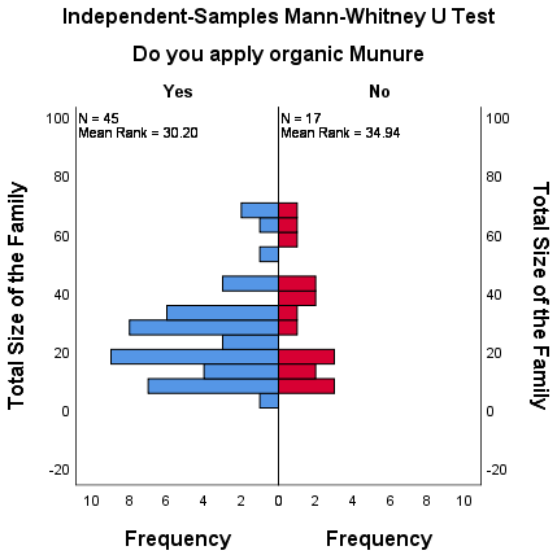

Independent-Samples Mann-Whitney U Test
Do you practice weeding
Yes
No
N = 13
Mean Rank = 27.42
N = 27
Mean Rank = 17.17
The amount of the Loan per Year
The amount of the Loan per Year
Frequency
Frequency

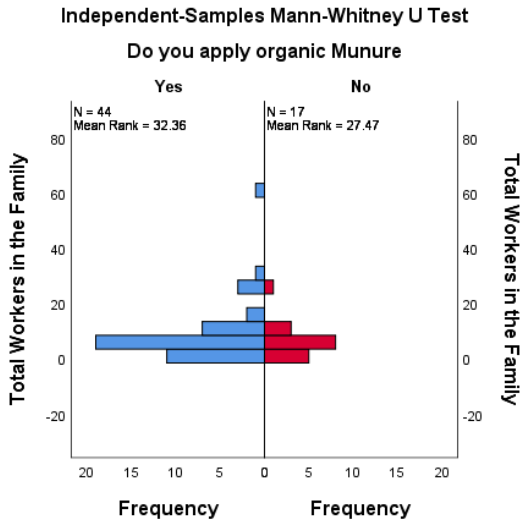
Annex V-f: Organic Fertiliser Application

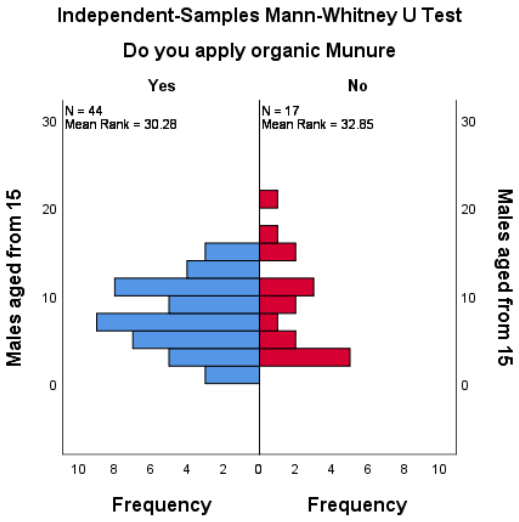
Chi-Square Tests Results Organic Fertiliser							
Factors	Chi-Square value	Continuity correction	Significance	Significance continuity correction	Df	Phi	Cramer's V
Education level (formal)							
Worker engagement frequency							
External worker engagement	3.69	3.69	0.05	0.11	1.00	0.24	0.24
Gender							
Membership of a FBO							
Access to government advisory service freq							
Access to government advisory service	11.52	9.20	0.00	0.00	1.00	0.43	0.43
Access to project NGO assistance	9.27	7.61	0.00	0.01	1.00	0.39	0.39
How did you know the SRI	8.99		0.01		2.00	0.38	0.38
Easy irrigation							
Easy drainage	6.97	5.53	0.01	0.02	1.00	0.34	0.34
Inundation	14.61		0.00		2.00	0.49	0.49
Difficulty to access chemical fertiliser							
Difficulty to access organic fertiliser	0.73	0.32	0.39	0.57	1.00	-0.11	0.11
Loan taking	0.00	0.00	0.98	1.00	1.00	0.00	0.00
Where or who do you take loan from							

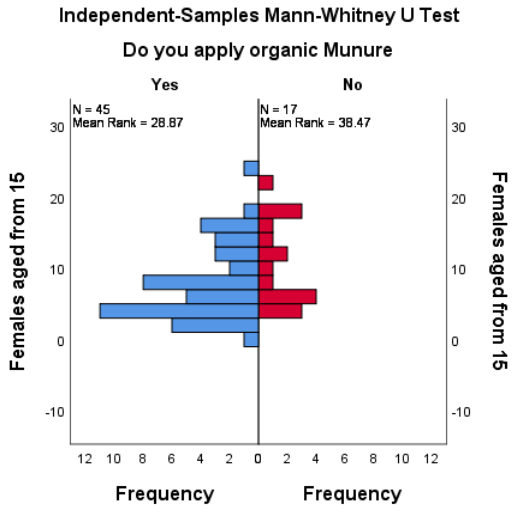
Mann-Whitney U results / Organic Manure							
Factors	Mann-Whitney U	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Mean Rank value		Median value	
				Yes	No	Yes	No
Age	220.00	-2.57	0.01	35.11	21.94	52.00	42.00
Size of the household	441.00	0.92	0.36	30.20	34.94	23.00	30.00
Total number of workers in the household	314.00	-0.97	0.33	32.36	27.47	6.00	5.00
Males above fifteen years old	405.50	0.51	0.61	30.28	32.85	6.00	8.00
Females above fifteen years old	501.00	1.87	0.06	28.87	38.47	6.00	10.00
Household members above fifteen years old	462.00	1.26	0.21	29.73	36.18	13.00	19.00
Size of the rice farm	334.00	-0.77	0.44	32.58	28.65	1.20	1.00
Total farm land	493.00	1.74	0.08	29.04	38.00	4.38	9.25
Transport equipment score	414.50	0.51	0.61	30.79	33.38	3.00	4.00
Land preparation equipment score	319.00	-1.25	0.21	32.91	27.76	0.00	0.00
Total score for all equipment	376.50	-0.09	0.92	31.63	31.15	10.80	14.40
Experience in rice production	242.50	-2.21	0.03	34.61	23.26	32.00	20.00
Experience in SRI application	112.00	-4.25	0.00	36.40	15.59	5.00	3.00
Amount of the loan	81.50	-2.37	0.02	23.19	13.41	250000	125000

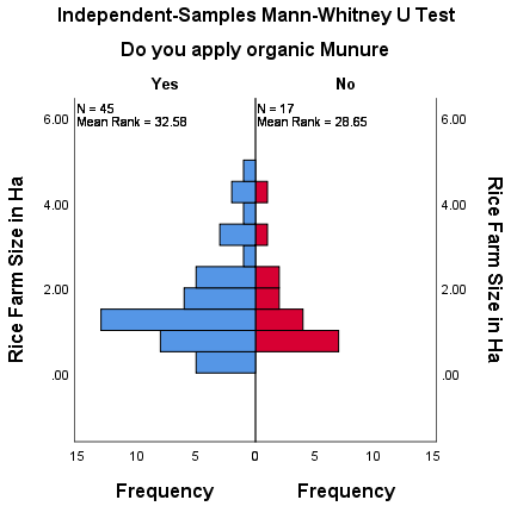

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 35.11
N = 17
Mean Rank = 21.94
Age
Frequency
Frequency

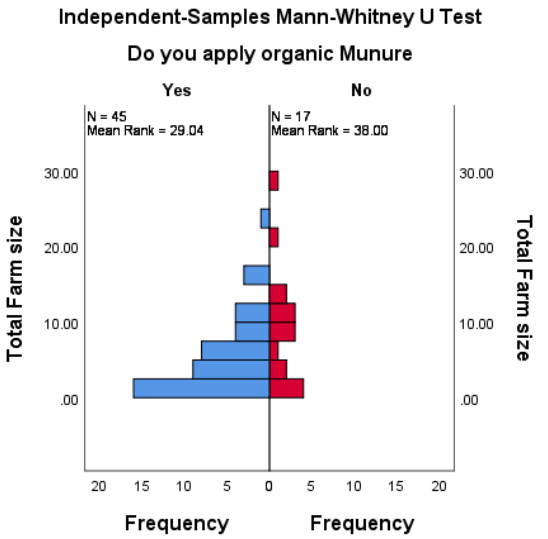

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 30.20
N = 17
Mean Rank = 34.94
Total Size of the Family
Frequency
Frequency

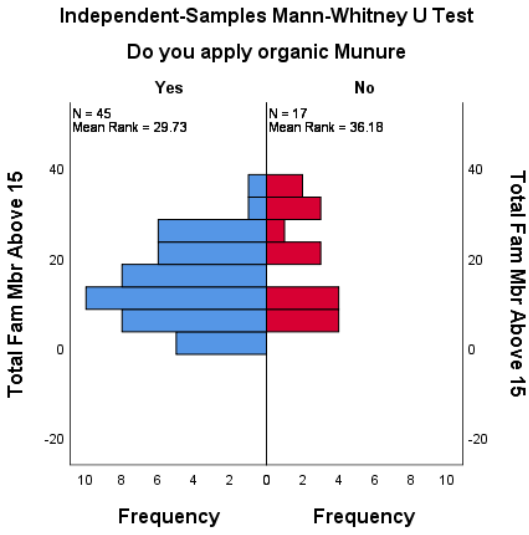

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 44
Mean Rank = 32.36
N = 17
Mean Rank = 27.47
Total Workers in the Family
Frequency
Frequency

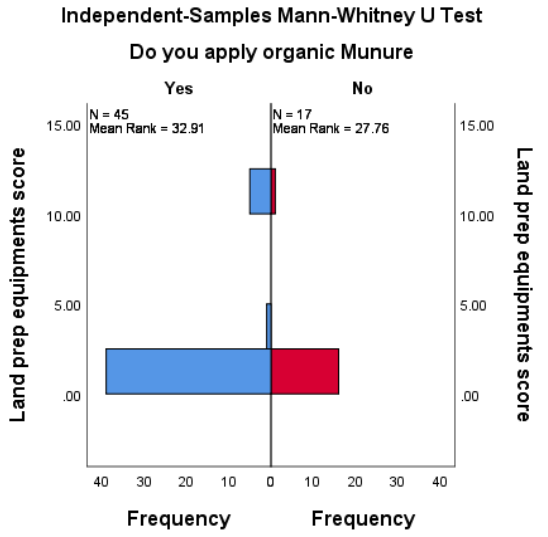

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 44
Mean Rank = 30.28
N = 17
Mean Rank = 32.85
Males aged from 15
Frequency
Frequency

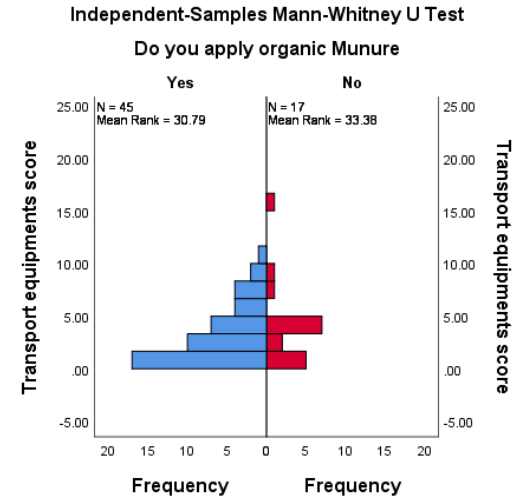

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 28.87
N = 17
Mean Rank = 38.47
Females aged from 15
Frequency
Frequency

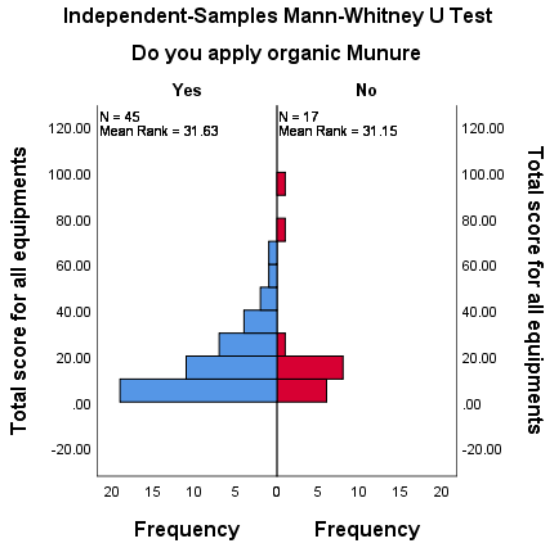

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 32.58
N = 17
Mean Rank = 28.65
Rice Farm Size in Ha
Frequency
Frequency

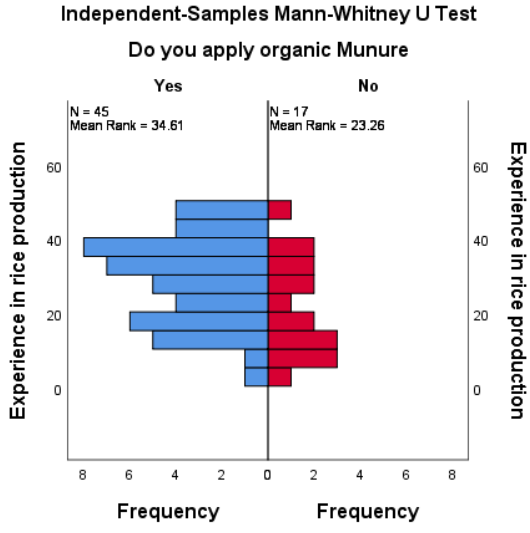

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 29.04
N = 17
Mean Rank = 38.00
Total Farm size
Frequency
Frequency

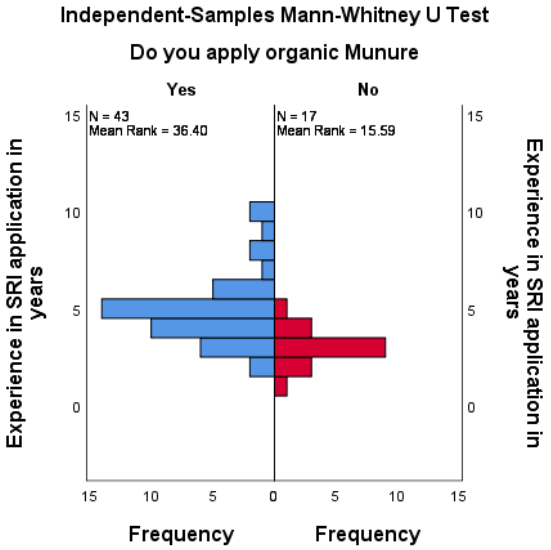

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 29.73
N = 17
Mean Rank = 36.18
Total Fam Mbr Above 15
Frequency
Frequency

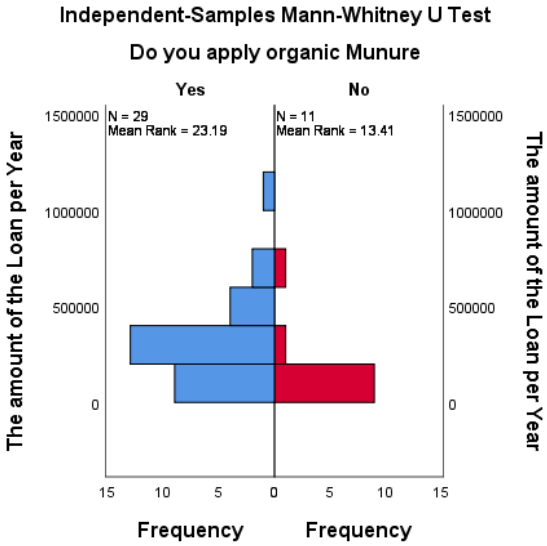

Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 32.91
N = 17
Mean Rank = 27.76
Land prep equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 30.79
N = 17
Mean Rank = 33.38
Transport equipments score
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 31.63
N = 17
Mean Rank = 31.15
Total score for all equipments
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 45
Mean Rank = 34.61
N = 17
Mean Rank = 23.26
Experience in rice production
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 43
Mean Rank = 36.40
N = 17
Mean Rank = 15.59
Experience in SRI application in years
Experience in SRI application in years
Frequency
Frequency


Independent-Samples Mann-Whitney U Test
Do you apply organic Munure
Yes
No
N = 29
Mean Rank = 23.19
N = 11
Mean Rank = 13.41
The amount of the Loan per Year
The amount of the Loan per Year
Frequency
Frequency

Annex VI: Publication(s)

(First paper published in October 2025 (attached); Second paper to be published in December 2025)

Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/21919
DOI URL: http://dx.doi.org/10.21474/IJAR01/21919

RESEARCH ARTICLE

BEYOND FARMERS' WILLINGNESS TO ADOPT THE SYSTEM OF RICE INTENSIFICATION: ROLE OF MANAGEMENT INSTITUTIONS AND PHYSICAL CONDITIONS IN MALI

Sidibé Mohamed[1,2], Dicko Mohamed[3] and Sidibé Amadou[1,2]

1. Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou, Mali.
2. Beta Gamma Research and Development (BGRD), Mali.
3. Institut d'Economie Rurale (IER), Mali.

Manuscript Info

Manuscript History
Received: 09 August 2025
Final Accepted: 11 September 2025
Published: October 2025

Key words:-
Management institutions, physical conditions, SRI, adoption, Mali

Abstract

Upon SRI's successes and expansion globally, the system was introduc ed in West Africa in recent years. It was simultaneously introduced in both Baguinéda and Sélingué irrigated schemes, in 2018, by the German Society for International Cooperation (GIZ) through its Green Innovation Centre (CIV). While adoption studies commonly focus on factors at farmers' level, this paper aimed to treat the role of the institutional environment and the physical conditions of the schemes in the adoption of SRI in Baguinéda and Sélingué, Mali. Purposive sampling technique was used to select hundred and twenty-one farmers in the two locations for individual interviews. The interviews were conducted through a questionnaire including questions on physical and institutional constraints preventing farmers to adopt SRI. In addition, two focus group discussions with farmers in each location and key informant interviews with management staffs and extension officers were also conducted. Results revealed the existence of operational problems within farmers' organizations as well as management offices. They also indicated that none of the parties, including Government, plays its full roles as indicated in the governing documents of the schemes and, these combined factors negatively affect SRI adoption. These results help understand that interventions aiming at SRI adoption should not be limited to targeting only farmers but should also address the management institutions and physical conditions of the intended locations.

"© 2025 by the Author(s). Published by IJAR under CC BY 4.0. Unrestricted use allowed with credit to the author."

Introduction:-

Upon SRI's successes and its expansion globally (Katambara et al., 2013; Noltze et al., 2013), the system was introduced in West Africa in recent years (Uphoff, 2016). According to Styger et al. (2011), the SRI was first tested in Mali in 2007, through 2009. The test program was implemented by an NGO named Africare which was intervening in Goundam and Diré circles. The NGO helped the communities to establish village-based small-scale

Corresponding Author:-Sidibé Mohamed
Address:-1. Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou, Mali. 2. Beta Gamma Research and Development (BGRD), Mali.

irrigation schemes (*Périmètre Irrigué Villageois*, PIV) of 30-35 ha each and irrigated by motor pumps to tackle food insecurity experienced by the local communities (Styger et al., 2011). On these PIV, the yields were higher than that of deep-water rice production system that farmers were practicing (4.9 t/ha compared to 750 kg/ha) but the land area allocated to households were still small (1/3 ha per household) (Styger et al., 2011). Therefore, it was necessary to find means to further increase the yields. It was in that context and perspective that the SRI was tested in Goundam and Dire circles. In 2007, the NGO Africare first tested the SRI with one farmer in the Douegoussou village, in Goundam circle; the results were outstanding (9 t/ha of paddy compared to 6.7 t/ha in the control plot), farmers in the area therefore expressed great interest in larger scale testing of the SRI (Africare Mali, 2008).

Based on these first results and farmers' interest, the Better U Foundation of Los Angeles, California, made a grant to Africare for a larger project: to assess the performance of SRI in 12 villages during the 2008–2009 growing season in the circles of Goundam and Diré. The main objectives were to: (a) adapt SRI principles to the local rice cropping system conditions, and (b) compare SRI practices with farmer practices in 12 sites within two administrative circles of the Timbuktu region. The SRI continued its expansion and involved different partners and NGOs. In 2015, the German Society for International Cooperation (GIZ) through its Green Innovation Centre (CIV) engaged in the promotion of the SRI. In 2018, CIV simultaneously introduced the SRI in both Baguinéda and Sélingué irrigated schemes. They trained some farmers and Government agents on the application of the six SRI principles and the Deep Urea Placement (DUP) technique. The trained farmers were also provided both required chemical and industrial organic fertiliser for the test plots. The used diffusion method was Farmer Field School (FFS) technique and the test program initially lasted for three years. This paper aimed to treat the role of the institutional environment and the physical conditions of the schemes in the adoption of SRI in Baguinéda and Sélingué, Mali.

Materials and Methods:-

Study locations:-

This study was conducted in Baguinéda (12°37'00" N, 7°47'00" W) and Sélingué (11°38′18″ N, 8°13′47″ W), in Mali, in 2022-2023. Sélingué is located in the North-Guinean zone (1000-1200 mm) of Mali and Baguinéda in the North Soudanian zone (800-1000 mm). Sélingué is a rural area located 140 km from Bamako, the capital city, while Baguinda is a peri-urban area located some 30 km from Bamako. The overall area covered by Baguinéda and Sélingué irrigated schemes are respectively 3000 and 1350 ha. The economic activities in Sélingué are structured around agriculture (rice production mainly), fishing and artisanal gold mining-developing in recent years. The construction of the dam and the irrigated scheme boosted several small businesses around rice production. In Baguinéda, which is closer to Bamako, in addition to agriculture as main activity of most of the population, the influence of the big city has settled. This brings many people in small businesses and spread land speculations.

SRI was introduced in Sélingué and Baguinéda by a project led by the Green Innovation Centre (CIV) of the German Corporation for International Cooperation (GIZ), in 2018. Farmers were selected across villages covered by the two irrigation schemes to participate in trials through Farmer School Approach (FSA). Several farmers were trained on SRI techniques and those chosen to accommodate the trials were given seeds and both chemical and industrial organic fertilizers required for their plots. The management institutions of the two irrigated schemes dedicated trained fields technicians to accompany farmers on the trials. The trials were financially supported by the project for three initial years. The promotion of the system to all the other farmers was led by the respective management institutions.

Management institutions of the irrigated schemes:-

Sélingué:-

The management of the irrigated scheme is jointly assured by the *Office de Développement Rural de Sélingué* (ODRS) created in 1996 (by the law "Loi n°96-042/AN-RM of august 7th, 1996"), the Government and the producers. Two management institutions preceded ODRS, the authority for the construction "*Autorité d'Aménagément de Sélingué*, 1977-1982", in charge of the resettlements and the construction activities, and the "*Office pour l'Exploitation des Ressources Hydrauliques du Haut Niger* (OERHN), 1982-1996", with the double purpose of electricity production and the rural development of the whole area including the management of the irrigated scheme. In 1996, the two missions were split, the dam and the electricity production were assigned to the national company of energies "*Energie du Mali*, EDM-SA" and the rural development and the management of the irrigated scheme to ODRS, created for the very purpose. For the current management, it is jointly assured by ODRS, the Government and the producers. The three parties, ODRS-Government-Producers are bound by a contract

document named "*Contrat-Plan*". This document which is renewed every three years stipulates the roles and responsibilities of each party for the operationalisation, extension and maintenance of the irrigated scheme. The Government is in charge of extending and maintaining the primary roads, irrigation and drainage canals, and the outlet infrastructure and equipment. The secondary roads, irrigation and drainage canals are maintained by ODRS while producers assure the maintenance of the tertiary ones and the gullies in their compartments. Besides, producers pay water usage fees to ODRS, and ODRS among other activities assures the assistance, training, input access facilitation and advisory service to producers for their production activities on and beyond the irrigated scheme. ODRS also elaborates the production calendar, controls and supervises its implementation.

Baguinéda:-

As similar to ODRS, the management of the Baguinéda irrigated scheme is also jointly assured by the *Office du Périmètre Irrigué de Baguinéda* (OPIB), the Government and the producers. They are also bound by the "*Contrat-Plan*" (renewed every three years) which stipulates that the Government is in charge of extending and maintaining the primary roads, irrigation and drainage canals. The secondary roads, irrigation and drainage canals are maintained by OPIB while producers assure the maintenance of the tertiary ones. Similarly, producers pay water usage fees to OPIB, and OPIB assures the assistance, training, input access facilitation and advisory to producers for their production activities on and beyond the irrigated scheme, elaborates the production calendar, controls and supervises its implementation. In both locations, farmers are associated to the management through joint committees "*les comites paritaires*" in charge of land and maintenance funds management.

These committees, presided by ODRS and OPIB are composed of sixteen members, eight representatives of producers and eight representatives of ODRS for Sélingué and OPIB for Baguinéda. The committees should be renewed every three years. These committees deliver on plots attribution, reattribution and retrieval. They also deliver on the use of funds intended for the reparation and maintenance of relevant infrastructures. These funds are constituted of water usage fees paid by all producers. The committees are also responsible for coaching farmers to proceed to the maintenance of tertiary canals and decide of sanctions in case of no execution. In addition to the "*Contrat-Plan*" and the joint committees, it is instituted that all farmers sign and respect operating conditions documents "*Cahier des charges*" with ODRS/OPIB. These documents legally bind ODRS/OPIB and farmers. They engage through this document to pay water usage fees, permanently cultivate their fields, clean and maintain the tertiary canals. The document also highlight that the plots should not be borrowed, rented, sold or inherited.

Presentation and description of the irrigated schemes:-

Sélingué:-

Structure and protection infrastructure of the scheme:-

The irrigated scheme is divided into fourteen sectors, numbered from 11 to 24. Each sector can be considered as an autonomous scheme, water-supplied by a secondary canal through a secondary inlet (on the main canal), and drained by a secondary culvert which drains into the main culvert of the scheme. Each sector is divided into elementary compartments with an average gross area of 6 ha and an average net area of 5.11 ha, after deduction of the areas occupied by the roads, irrigation and drainage canals. With its 872 ha of net area dedicated to rice, there are 170 compartments. The compartments are grouped in fours (4) to form a sub-sector, water-supplied by a tertiary canal through a tertiary inlet (on the secondary canal which borders the sector to the south), and drained by a tertiary culvert which drains into the secondary culvert bordering the northern sector.

The scheme is protected in the south by the platform of the hydroelectric dam and on the west, between the scheme and the Sankarani river bed, by an elevated dike of 13,545 m long with a width of 4.50 m. This is necessary because of the risk of the plain being submerged by flooding from the river. At the downstream end of the scheme (lowest point), where the main culvert C1 which collects excess water from the scheme opens out, the dyke is equipped with a structure for draining water into the river. This structure consists of a quadruple gravel drainage pit, equipped with non-return drainage valves, and a drainage pumping station. This pumping station is equipped with three electric generators, whose role is to ensure the drainage of the scheme when the water level of the river, in flood, is higher than that of the plain and when, consequently, drainage by gravity has become impossible. In the east of the scheme, parallel to the main irrigation canal P1, a channel was created to drain run-off water from outside plateau till the river.

Irrigation network:-
The scheme is equipped with one water intake (with a capacity of 3 cubic meter per second). This intake provides water to the main irrigation canal sectioned in two, therefore considered as two irrigation canals, P1 and P2. The total length of the two main irrigation canals is 10.7 km, 6,522 m for P1 and 4,201 m for P2. To the main irrigation canals are connected thirteen secondary irrigation canals, it could be counted fourteen if one considers the fact that P2 plays the role of secondary irrigation canal by directly receiving tertiary irrigation canals on its section crossing longitudinally the scheme. The total length of the thirteen secondary irrigation canals is 11.8 km. Each secondary irrigation channel irrigates through the tertiary irrigation canals a separate and independent sector. In other words, a sector is the sum of the compartments irrigated by the same secondary irrigation canal. To the secondary irrigation canals and P2 for its concerned section, are connected 50 tertiary irrigation canals with a total length of 27.99 km. Each tertiary irrigation canal irrigates a set of four compartments, called a sub-sector. The total length of the three levels of irrigation canals is 50.5 km. The tertiary irrigation canals provide water to gullies in each compartment, and plots are irrigated from the gullies. The net area per rice production compartment being 5.11 ha, we can deduct that there are 611 m of irrigation gully per compartment, and similar for drainage. The system of irrigation on the scheme is gravitational.

Drainage network:-
There are drainage gullies in the comportments that drain water into the tertiary culverts, which drain into the secondary culvert to finally end in the main culvert, before returning into the river. Similar to irrigation gullies, there are on average 611 m of drainage gullies per compartment. Like tertiary irrigation canals, there are 50 tertiary culverts, with a total length of 23 865 m. There are fourteen secondary culverts, numbered from C11 to C24, with a total length of 14 100 m. The main culvert is 10 285 m long. The total length of the drainage culverts (tertiary, secondary and main) is 48.25 km.

Roads network:-
The scheme is equipped with some primary, secondary and tertiary roads. The primary or main roads, along the main irrigation and drainage canals, have a width of 6 meters and a total length of 22 050 m. The secondary roads, along the secondary irrigation canal, have a width of 4.5 m and a total length of 13 700 m. The tertiary roads, or compartments interconnecting roads, have a width of 3 m and a total length of 26 750 m. In sum, the total length of all the roads is 62.5 km.
Each sector is crossed along its longitudinal axis by an interconnecting route that provides access to each compartment at all times of the year.

Baguinéda:-
Structure and protection infrastructure of the Scheme:-
While the Sélingué irrigated scheme is subdivided following the irrigation canals, the Baguinéda irrigated scheme is subdivided according to villages and groups of villages. However, to make the parallel with Sélingué, we decided to refer to the irrigation network for better and easy understanding. There are four sectors which are Sector I (Kobala-Coura), Sector II (Baguinéda-Camp), Sector III (Sébéla) and Sector IV (Tanima). Each sector is divided into sub-sectors following the secondary canals and into blocks following the tertiary canals. Sector I has seventeen subsectors. There are twelve, six and seventeen sub-sectors for Sector II, III and IV respectively. The average block size is 6.76 ha. With regards to the protection of the scheme, there are 25 km of protective dyke.

Irrigation network:-
The irrigated scheme is water-supplied by the Niger river from the dam called "*Barrage des aigrettes*" and at its end, the drainage water also returns to the same river. The water intake has a maximum capacity of 12.5 cubic meter per second. This dam "*Barrage des aigrettes*" also supplies water to the Sotuba hydro-electric power central. The system of irrigation on the scheme is gravitational. In each sector, the secondary canals are connected to the primary one. There are fifty-two secondary irrigation canals. These fifty-two secondary canals are split into seventeen secondary canals for sector I, twelve for sector II, six for sector III and seventeen for sector IV. The secondary canals supply water to the tertiary ones which in turn irrigate the fields through the gutters. The main irrigation canal has a total length of 37 km, going from Bamako to the exit into the Niger river, and the fifty-two secondary irrigation canals and the four hundred and forty-two tertiary irrigation canals measure 56 km and 144 km, respectively (Héritier, 2017). There are 2 331 gutters in total and seven regulators, regulating water at some sections on the main irrigation canals.

Drainage network:-
Similar to the irrigation network, there are primary, secondary and tertiary drainage culverts, in addition to drainage gullies at blocks' level. The drainage gullies in the blocks drain water into the tertiary culverts, which drain into the secondary culvert to finally end in the main culvert, before returning into the river. The main drainage culverts measure 35 km, and the secondary and tertiary culverts measure 59 and 174 km, respectively.

Roads network:-
To ensure good traffic flow across the scheme, a network of carriageways has been built along all the irrigation canals (from the main canal to the tertiary ones), secondary and tertiary culverts. In total, there are 47 km of main roads, 56 and 144 km of secondary of tertiary roads.

Data collection and analysis:-
Purposive sampling technique (Ilker et al., 2016) was used in this study to select hundred and twenty-one farmers in different villages of the two locations (sixty-one in Baguinéda and sixty in Sélingué) for individual interviews. The interviews were conducted through a questionnaire including questions on physical and institutional constraints preventing farmers to adopt SRI. In addition, two focus group discussions with farmers in each location (male and female groups of ten people each) and key informant interviews with management staffs and extension officers were also conducted (including six people in Sélingué and five people in Baguinéda). The collected data were analysed through content and thematic analyses methods. EXCEL and SPSS software were used for frequencies and patterns.

Results and Discussion:-

Management of the schemes:-
If the architecture and logic of the management of the schemes, as mentioned above, is sound, focus group discussions with both sides revealed complicated functioning. In fact, results indicates that different parties hardly execute their responsibilities. In Sélingué, the primary irrigation and drainage canals (Government's responsibility) are not cemented (for most part of it) and that leads to water loss through percolation and infiltration and therefore limits the irrigation capabilities. The electric pumps at the outlet of the irrigated scheme have not been operational since around 2007, according to farmers and confirmed by staff members. This renders the scheme vulnerable to floods through return of water from the main bed of the river. Such floods occur in case of heavy rain or release of water by the Sélingué hydroelectric power dam in order to protect their own infrastructure from too high-water levels. In addition, in both locations, farmers reported that the maintenance of the secondary irrigation and drainage canals (ODRS/OPIB responsibility) are not properly done. Visiting the two schemes, holes and breaks could easily be observed on parts of these canals. Though the situation seems worser in Sélingué than in Baguinéda.

Elsewhere, the management staffs of both locations reported that farmers do not respect their engagements as per the operating conditions document "*Cahier des charges*". In fact, despite sensitisation, not all farmers clean or repair the tertiary canals. They proceed to rental, borrowing and merchandising of plots. The inheritance is also systematic. During discussions with farmers, these information were not refuted. However, some famers in Sélingué indicated that though cleaning of the tertiary canals falls onto them, it is very difficult for them to proceed to it because of their depth and the presence of snakes. They added that if one is bitten by a snake, one will have to spend a lot of money to get cure, lose that campaign or eventually one's life. Moreover, in Sélingué, it was common to see farmer-installed pipes cutting through the irrigation or drainage canals, or circulation roads, destined to either irrigate or drain water from the plots, against the set rules. This situation was not observed in Baguinéda. However, a few farmers in Baguinéda indicated they use their motored pumps to irrigate their plots in case of dry spell and lack of irrigation water. The difference could be due to the fact that rice production is done in Baguinéda exclusively during the rainy season.

Furthermore, the operationalisation of the joint committees seems challenging. In fact, it was reported that meetings are not held as frequently as they should be and the renewal of the committee members as for the representatives of the farmers seems problematic. In Sélingué for example, a committee established in 2009 and that was supposed to be renewed in 2012, was actually renewed in 2016. This clearly reveals disagreement among farmers and the inability of ODRS to assist on that. Such cases were not reported in Baguinéda. These results shows that none of the parties in both schemes respect fully their engagement. The non-respect of the management rules by both parties in these two schemes appeared as hinderance to SRI adoption since they affect water control, irrigation, drainage and floods occurrence on the schemes.

Partnership, advisory service and awareness delivery:-
In their intervention areas as per their assigned objectives, OPIB/ODRS are in charge of providing advisory service to farmers. They promote validated good agricultural practices, manage Government fertiliser subsidy program, create and facilitate partnership between farmers and other assisting organisations like NGO/Projects, universities and research institutions. In addition, they facilitate farmers' access to credit for inputs and equipment through partnership with financing institutions. This, altogether, is supposed to increase farmers knowledge and facilitate their access to equipment for better incomes and improved livelihoods.

However, on the delivery of these services, there was a lot of mutual accusations. From the discussions with farmers, they complained that the fertiliser subsidy program is not satisfactory. They reported delay in the provision, selectiveness and discrimination. They stated that big producers and farmers in good terms with agents are prioritised over neutral and small land owners. Moreover, they mentioned that the same discrimination and selectiveness continues when it comes to designating participants for new training programs or in case of assistance from a new project for example. They also indicated that it is a small group of farmers benefiting everything while all the rest is left behind. On the other side, agents from both locations indicated their limited number and logistic means to properly engage with all farmers directly. They therefore pass through farmer organisation leaders to reach the others and also use radio communication means. Or, difficult functioning of farmers' organisations, affinity problems and non-involvement of all farmers in the organisations seems not an adequate environment for this option to work properly.

The need for a proper delivery of the advisory service is clearly reported to be important in contributing in the adoption of SRI principles. In fact, access to advisory service has been identified as contributing factor in the adoption of four out of the six SRI principles in our study. In addition, engagement with NGO/Projects which itself is related to the advisory service has been identified as contributing factor in the adoption of two out of the six SRI principles. Therefore, the non-effectiveness of these services and collaborations in the study areas hinders SRI adoption. In line with our findings, Sattler and Nagel (2010) confirm that the components of the diffusion environment are part of the adoption determinants. In addition, Moore et al. (2024) indicated that participation to trainings (which is mostly coordinated through partnership and extension service) is part of the significant predictors of SRI adoption. Kabir et al. (2024) indicated that some of the major constraints to SRI adoption include inadequate training and limited market access-which could also be facilitated by management institutions (extension service). Moreover, Mkubya et al. (2023) showed that access to extension service has positive impact on SRI adoption, and Mhango (2024) confirmed that the knowledge of farmers has significant influence on adoption of SRI.

Physical conditions of the schemes:-
As indicated earlier, with the irrigation and drainage equipment and installations working properly no flooding should occur in the two schemes. However, fifty percent of SRI nonadopters from our sample from Sélingué mentioned water level control as a problem dissuading them from practicing SRI. The same issue was mentioned by 8.57 percent of those from Baguinéda. This indicate that there are more drainage related issues in Sélingué than in Baguinéda. However, with regards to irrigation, Sélingué is more water supplied than Baguinéda due to the fact that Sankarani is a tributary of the Niger River, which at the same time exposes Sélingué to the occurrence of more floods than Baguinéda. This relative easiness of irrigation explain why rice is produced in Sélingué during the two seasons and only during the rainy season in Baguinéda.

In both locations, field visits and discussions with both management staff and farmers revealed that most farmers have increased their plot size by encroaching on roads, irrigation and drainage canals margins. This has created situations where water infiltrates easily from one plot to another and therefore hindering the application of some SRI principles like Early Age Transplanting (EAT), Alternate Wetting and Drying (AWD), Organic Fertiliser Application (OFA) and weeding to some extent. This situation coupled with the non-synchronous activities in the schemes renders water management challenging in the two locations. Moreover, it is shared by both sides (farmers and OPIB/ODRS) that some sectors in both schemes are not well planned (elevated than the others), which renders their irrigation more difficult despite the water level. These infrastructural problems which further complicate the SRI adoption falls on the responsibility of the Government and ODRS/OPIB.

Conclusion:-

This study analysed the importance of management institutions and physical conditions in the adoption of SRI in Baguinéda and Sélingué irrigated schemes, Mali. Results revealed that in both locations, there are operational problems within farmers' organizations as well as management offices. None of the parties, including Government, plays fully its roles as indicated in the governing documents of the schemes. This situation emphases the difficult physical conditions reported by respondents in the two irrigated schemes. Therefore, as indicated in several studies, the combination of these factors negatively affects SRI adoption. These results point out that SRI adoption is a complex process that goes beyond farmers willingness to adopt different principles. It requires interventions on training and sensitization of farmers but primarily the creation of adequate institutional and operational physical conditions enabling SRI adoption.

Acknowledgements:-

We are grateful to the German Federal Ministry of Education and Research (BMBF) through the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) for fully funding this research. We are also grateful to farmers and staff of both Baguinéda and Sélingué irrigated schemes.

References:-

1. Africare Mali. (2008). The System of Rice Intensification (SRI) First Experiences from Timbuktu – Mali; Farmer-led SRI test in Goundam – 2007/2008. Africare Mali, Bamako, Mali. http://sri.ciifad.cornell.edu/countries/mali/MaliAfricare200708.pdf
2. Héritier Rutabara (2017), La perception de l'entretien du réseau de drainage et sa solution selon les agriculteurs- Étude de cas de Baguinéda Amont (OPIB / Mali), Master thesis, 2iE, Ouagadougou.
3. Ilker, E., Sulaiman, A. M., Rukayya S. A. (2016). Comparison of Convenience Sampling and Purposive Sampling. American Journal of Theoretical and Applied Statistics. 5, (1), 2016, pp. 1-4. https://doi.org/10.11648/j.ajtas.20160501.11
4. Kabir, A. M., Murtala, N., Garba, M., & Abu, I. A. (2024). Determinants of Adoption of System of Rice Intensification (SRI) Practices Among Male Rice Farmers in Kano State, Nigeria. Nigerian Journal of Agriculture and Agricultural Technology, 4 (4B), 270–281. https://njaat.com.ng/index.php/njaat/article/view/921
5. Katambara, Z., Kahimba, F., Mahoo, H., Mbungu, W., Mhenga, F., Reuben, P., Maugo, M. and Nyarubamba, A. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. Agricultural Sciences, 4, 369-375. https://doi.org/10.4236/as.2013.48053
6. Maya Moore, Kimmerling Razafindrina, V. Ernesto Méndez & Meredith T. Niles (2024). An analysis of the adoption of the "system of rice intensification" (SRI): why a homegrown technique has yet to take seed among rice farmers in Madagascar, Cogent Food &Agriculture, 10:1, 2319932. https://doi.org/10.1080/23311932.2024.2319932
7. Mhango Solomon S. (2024). Factors Influencing Adoption of System of Rice Intensification among Smallholder Farmers in Mvomero District, Tanzania. International Journal of Multidisciplinary Research and Analysis. ISSN (print): 2643-9840, ISSN (online): 2643-9875. https://doi.org/10.47191/ijmra/v7-i02-33
8. Mkubya R.W., Damas P. and Mahoo H.F. (2023). Socio-Economic Factors Influencing the Adoption of SRI among Smallholder Rice Irrigation Farmers in Morogoro Region, Tanzania. Tanzania Journal of Agricultural Sciences (2023) Vol. 22 No. 1, 169-183
9. Noltze, M., Schwarze, S. and Qaim, M. (2013). Impacts of natural resource management technologies on agricultural yield and household income: The system of rice intensification in Timor Leste. Ecological Economics, 85, 59-68.
10. Sattler, C., and U.J. Nagel. (2010). Factors affecting farmers' acceptance of conservation measures – A case study from north-eastern Germany. Land Use Policy 27: 70–77
11. Styger E. (2011). Introducing the System of Rice Intensification (SRI) to irrigated systems in Gao, Mopti, Timbuktu and to rainfed systems in Sikasso, 2009/2010. Consultancy report for Abt Associates, Bamako, Mali
12. Uphoff, N. (2016). The System of Rice Intensification (SRI)-Responses to frequently asked question. SRI-Rice, B75 Mann Library, Cornell University, Ithaca, New York 14853, USA. 226p. ISBN: 13: 978-1515022053. https://sri.cals.cornell.edu/aboutsri/SRI_FAQs_Uphoff_2016.pdf