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System of Rice Intensification in Nepal: Determinant factors for adoption, and relevance to climate change

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DECLARATION

I, Surabhi Khanal, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended.

Signature.....................................

Date..

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ABSTRACT

Until the year 1985, Nepal used to be a net exporter of rice. During the 1960s, Nepal was exporting rice worth $45 million to India, annually. Compared to the current times, in the year 2015, Nepal imported rice worth $210 million from India. Decrease in land availability for agricultural production. The country faces major challenges in rice production, such as low productivity, low soil fertility, land degradation, and climate-change impacts. The System of Rice Intensification, an alternative rice production technique offers a sustainable solution to all these challenges. The System of Rice Intensification as a new agricultural innovation has been disseminated in Nepal, since the trials began in 1999. SRI is an agro-ecological methodology to increase the productivity of irrigated rice. The productivity of rice is increased by changing the management of water, soil, plants, and nutrients. However, since the majority of Nepalese farmers are accustomed to conventional rice farming methods, the adoption of SRI is taking a slow lane. The objectives of this thesis was to a) the adoption behavior of the farmers concerning the determinant factors of SRI adoption and b) compare(to conventional system) and potential environmental benefits of SRI in the context of climate change. I analysed the findings by making use of the Agriculture Innovation System Approach and Adoption and Diffusion theory. Concerning research design, this research is qualitative in nature. Both, primary sources and secondary sources were used for data collection purposes. By conducting thematic analysis of the gathered relevant data, results were developed. The major determinant factors that influenced the adoption of SRI by the farmers were factors such as labor demands, mechanization options, research and extension, irrigation facilities. However, outreach, extension practices and policies will be necessary to accelerate the implementation and adoption of the system of rice intensification for the benefit of farming households and the entire Nepali population, In addition this will assist in preserving the natural environment. Hence, SRI can best be promoted by investments in research and extension, initiatives that promote mechanization and irrigation services.

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Abbreviations

AIS	Agriculture Innovation System
ATA	Appropriate Technology Asia
AWD	Alternate Wetting and Drying
CIMMYT	International Maize and Wheat Improvement Center
DFID	Department for International Development
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
FFS	Farmers Field School
GDP	Gross Domestic Product
IDT	Innovation Diffusion Theory
IMF	International Monetary Fund
INGO	International Non-Governmental Organization
MoAD	Ministry of Agricultural Development
MRPP	Mega Rice Production Program
NITC	National Information Technology Center
NGO	Non-Governmental Organization
NRRP	National Rice Research Program
SRI	System of Rice Intensification
USAID	United States Agency for International Development

Chapter 1: Introduction

Nepal, is a country of unconstrained biodiversity. The country is associated with exceptional topographic, climatic, and agro-ecological conditions (Bhusal, 2019). With 68 percent of the population engaged in agriculture, this sector contributes to 27 percent of the total GDP of Nepal (Prasain, 2019; USAID,2021; NITC, 2021). One of the major impediments to agricultural development is that, only 28 percent of the total agricultural land in Nepal is irrigated (Gajmer, 2014). The factors that threaten this sector are climate change, and its impacts on agriculture such as unprecedented fluctuation in temperature, solar radiation potentially affecting crop production. Impacts such as drought, severe floods, landslides are additional effects of climate change. The diversity associated with its topography, and social vulnerability has accounted for the country's susceptibility to geological and climate related risks (Malla, 2008).

Nepal is an agricultural country with paddy cultivation from 3000m in the Sinja valley to the plains of Illam at 100m height (Shoemaker, 2017). Until the year 1985, Nepal used to be a net exporter of rice. During the 1960s, Nepal was exporting rice worth $45 million to India, annually. Compared to the current times, in the year 2015, Nepal imported rice worth $210 million from India (Gajmer, 2014). Nepal, has an annual average deficit of 1 million tons of rice, even when blessed with good monsoon seasons. Access to irrigation is a major limiting factor in rice production in Nepal. Only 18 percent of the cultivated land in Nepal has access to irrigation facilities (SRI International Network and Resources Center, 2015).

The unprecedented effects of climate change, rapid urbanization of fertile valleys, and out-migration of the young labor force has also threatened Nepal's rice production (Gajmer, 2014). In this context, the System of Rice Intensification (SRI) can increase production of rice while using less seedlings and water. To achieve food security in the given context of climate risks, urbanization, and less labor availability, SRI could be a suitable agricultural innovation to fulfill this objective. To achieve this objective, it is vital to study the factors that affect SRI adaptation by the farmers and what influences their choices of new techniques such as SRI. Because the implementation of SRI is focused on the adaptation of this technique by the farmers, they are the pivotal point (principal users) that determines the future of rice production based on SRI. This comparative study of SRI and traditional rice farming methods is based on empirical evidence from Nepal. The study highlights the advantages and disadvantages of SRI in Nepal. Further, this study also suggests the most promising factors in SRI that can increase production. As changes due to climate change are expected in the field of agriculture, it is also imperative to study how SRI can change the conventional rice farming techniques thereby building a system of rice production less vulnerable to climate change.

1.2 Thesis objectives:

1. To identify the determinant factors for adoption of SRI
2. To evaluate the advantages of SRI over traditional rice cultivation methods
3. To evaluate how SRI can be useful concerning climate change

1.3 Research questions

1. What are the determinant factors influencing farmers' adoption of SRI?

3. What are the technical and environmental advantages of SRI as a rice farming technique in comparison to the traditional rice farming method?

4. How can SRI be functional and rewarding to build climate resilience?

Chapter 2: Literature review

2.1 Agriculture in the third world with reference to Nepal

As 85% of the farmers in the developing countries produce on less than 2 hectares of land (Meyer, 2009). The majority of the farmers in developing countries are therefore small-scale farmers. Many of these developing countries have a high share of agriculture in the overall GDP (Meyer 2009). The agriculture sector is therefore critical to foster economic growth in these regions.

In the context of Nepal, the share of the agriculture sector in the GDP has decreased over the past years. The share of agriculture in GDP was 69% in 1974/75, 31% in 2009/2010 (Satyal, 2010), 34% in 2014/2015 to 26.98% in the fiscal year 2018/2019 (Prasain, 2019). Agriculture in Nepal is characterized by subsistence farming. The agricultural sector performs poorly with low productivity, restricted access to markets, high costs of food production and transportation, rugged terrain, meager economic return and exposure to natural disasters and climate change (Hussain, Rasul, Mahapatra, & Tuladhar, 2016). These problems have furthermore been compounded by labor out migration. The pattern of the decline in the share of agriculture in the GDP of Nepal is accompanied by the decline in the active population who are engaged in agriculture from 95% in 1971 to 60% in 2001 (Satyal, 2010). The decline in engagement of the active population in agriculture has been accompanied by out-migration, where small-scale farmers, deprived of sufficient income/stability from agriculture have chosen to fly abroad as laborers (Satyal, 2010).

The previously agricultural country has now become a remittance-based economy. Now, remittances from migrant workers contribute up to 32% of Nepal's GDP, with a growth of 11.1% of remittances in the first half of fiscal year 2020-2021 (Republica, 2021). This projects the shift of manpower from the agriculture sector to foreign employment. Another reason behind the decrease of youth engagement in agriculture is linked to preference of non-farm works by the educated youth in Nepal. This preference leads to abandonment of agricultural land (Maharjan, Kochhar, Chitale, Hussain, and Gioli, 2020).

2.2 What is SRI?

Over the last century, new innovations and transformations in the field of agricultural systems have been witnessed. Agricultural intensification, which is also used interchangeably with the term 'crop intensification' is traced back to the 1950s, during the green revolution in Asia. Agricultural intensification is achieved by increasing labor, capital and other inputs in the agricultural system resulting in an increase in the output per unit area of agricultural production (Carswell, 1997). SRI is an example of crop intensification practice in the context of rice cultivation. SRI was developed in Madagascar by a French agronomist Henri De Laulanié in the early 1980s. SRI is an agro-ecological methodology to increase the productivity of irrigated rice. The productivity is increased by changing the management of water, soil, plants, and nutrients (SRI International Network and Resources Center, 2015). Basically, SRI management practices include (i) early transplantation of young (less than 15 days) rice seedlings, (ii) single and widely spaced plantation of seedlings, hence reducing plant density, (iii) maintenance of soil in an aerobic state, in some instances even including dry phases for some days, hence saving a substantial amount of water, (iv) regulating weed control with a rotary weeder (preferably) to aerate the soil instead of weed suppression or use of herbicides; (v) usage of organic fertilizers such as compost, manure, green manure etc (De Laulanié 1993; De Laulanié 2003, as cited in Uprety, 2016). The foundation of SRI is based on the plant physiological theory on tillering by Japanese rice scientist Katayama. This concept of tillering consists of management practices that create conditions that allow rice plants to achieve full inherent growth as well as the production potential (Uprety, 2016).

After being introduced in the Anglophone scientific world, its yield was reported to increase, by saving resources simultaneously; water, nutrient, pesticides (Barison, 2002; Koma, 2002; Anthofer, 2004; Satyanarayana, 2004; Kabir ,2006; Sato, 2006, as cited in Uprety, 2006). Then, after its success this practice was introduced in Asia, Africa, and South America. It is currently practiced in over 50 countries. With its expansion around the world, it has raised a debate on the ineffectiveness of the conventional rice cultivation method (Thakur, 2010). In research conducted to study the ecological and economic benefits of SRI for food security and resource conservation in Tamil Nadu (India) it resulted in increased rice production by an average of 26 percent (and more). With the increase in rice production, it also contributed to saving up to 40 percent water through the process of alternate drying and wetting systems (Barah, 2010).

Despite the technical merits and concrete results that highlights the potentials of SRI, it is claimed that this practice is also relevant as a social phenomenon. But more empirical evidence is required to understand its uptake and functioning as an agricultural practice (Berkhout & Glover, 2011). The practice of SRI is not only limited to how it works and its results on rice crops but to a wider perspective of social dynamics, for example, labor availability, costs, beneficiaries, policies etc. (Glover, 2014).

2.3 SRI in Nepal

The trials of SRI in Nepal were initiated in 1998 by a government agronomist at the Khumaltar Research Farm in collaboration with the USAID, CRSP program. Most of these early trials began at sites near Kathmandu and Rupandehi district (SRI International Network and Resources Center, 2015). In 2001, CIMMYT and ATA started working with SRI methods in some districts like Kathmandu, and Rupandehi. Despite the initiation of SRI in Nepal, results at Khumaltar research station in Kathmandu were not encouraging at the end of the project. However, in 2002-2003, under a DFID funded project in Terai region of Nepal, rice plantation using SRI was carried out in Morang district, which finally generated encouraging results. The results from these trials encouraged the farmers to continue testing SRI in the field (SRI International Network and Resources Center, 2015; Uprety, 2006). From 2003 onwards, dissemination of SRI practices was carried out based on the evaluation of the results in the site of Morang by the District Agriculture Development Office.

The involvement of the District Agricultural Development Office in 2003 resulted in SRI gaining momentum in Nepal. The evaluation of SRI began with one trial of only 100 m^2 in 2003, and by 2005, the number of SRI farmers in Morang district reached 1,400 with SRI yield average of 6.3 t/ha compared to the 3.1 t/ha yields derived from conventional farming (Khadka, Dhital, Pandey, Uprety, & Uphoff, 2021). Further demonstrations and trials started generating positive results which led to the involvement of other governmental agencies such as the Department of Agriculture, Department of Irrigation and the Poverty Alleviation Fund, NGO such as the Emergency and Rehabilitation Coordination Unit of the UN Food and Agriculture Organization (ERCU/ FAO) started getting involved with SRI dissemination (Khadka et. Al, 2021).

2.4 SRI as an innovation for farmer's empowerment and towards sustainable agriculture

Farmer's subjective preferences of new agricultural incentives can influence their adoption behavior. It leads to accumulation of knowledge and adjustment of preliminary perceptions influencing their attitude towards adopting a new method or a technology (Meijer, Catacutan, Ajayi, Sileshi, and Nieuwenhuis, 2015). Therefore, the knowledge and perception of the farmers that influence the decision for adoption of innovations such as SRI are intrinsic factors. Whereas the external environment and the structural characteristics are the extrinsic factors that influence the farmer's decision to adopt new innovation (Meijer et al., 2015). Thus, it is important that the farmers are encouraged to participate in formulating practical ways to grow crops in a sustainable way. SRI may provide a dynamic interaction between farmers, researchers, and trainers, each having a distinct role to contribute with knowledge creation and innovation (Mishra, Whitten, Ketelaar, & Salokhe, 2006).

In the context of developing countries, millions of smallholder rice farmers experience a huge gap between their potential and actual farm yield (Papademetriou et al., 2000; Stoop & Kassam, 2005; McDonald et al., 2006, as cited in Mishra et al., 2006). In this context, SRI offers a set of management practices that farmers can evaluate and then adopt to meet their requirements based on their local conditions in contrast to adopting some predefined set of practices. Basically, this method depends less on external factors and is dependent on farmers acquiring knowledge and using that knowledge to become experts at growing healthy crops

(Uprety, 2006). However, as SRI is basically a work under progress, this concept has now been extended towards other crops (Uphoff & Kassam, 2008).

2.5 SRI: As adaptation to climate change

One of the biggest challenges of the future is to increase food production by using less water. 70 percent of freshwater in the world is used by crops and livestock generally, and up to 95 percent in developing countries. Paddy alone contributes to consuming 60 percent of it (Andrea, 2018). Therefore, changes in the current cropping techniques require immediate attention based on the data trade-offs between rice yield, water management and greenhouse gas emissions. It is estimated that by 2090, the global caloric production from maize, soybean, wheat, and rice will drop by 8-24% as a result of climate change (Elliott, Deryng, Müller, Frieler, Konzmann, Gerten, & Eisner, 2014) if no actions is taken. Rice being the most important staple crop of Nepal, supplies about 40% of the food calorie intake in Nepal, and contributes to nearly 20% of the agricultural gross domestic product. It also contributes about 7% to the overall GDP of Nepal (MoAD, 2015).

As a result of climate change, rice agro-ecology is highly vulnerable. However, farmers are unaware about climate change and its impact on rice production. So, there is a need for climate resilient adaptation strategies that are based on local context (Gahatraj, Jha, & Singh, 2018). For example, a reduction of CH_4 emission has been obtained through the application of SRI in Nepal. The emission of methane (CH_4) was measured using closed chamber techniques from fields using conventional farming system and system of rice intensification methods of upland i.e., Bari and lowland i.e., Khet. As a result of the comparative study, the SRI system reduced CH_4 emission by four times compared to the conventional agriculture system, contributing to climate change mitigation (SRI International Network and Resources Center, 2015).

2.6 Governmental Initiatives:

2.6.1 Rice Research Program

The National Rice Research Program (NRRP) was established in 1972 under the Department of Agriculture (DoA). In July 1995/96, Hardinath farm was handed over to Nepal Agricultural Research Council (NARC). The mission of NRRP is to contribute to poverty reduction and food security through increased productivity and production of rice in a sustainable way. To achieve this mission NRRP works on developing high yielding and stress tolerant rice varieties and sustainable production technologies in Nepal (NARC, 2017).

2.6.2 Mega Rice Production Program (MRPP) in Nepal

Amid growing concern of the import surge of rice in Nepal, Government of Nepal, through its policy & program and budget speech for fiscal year 2015/16, launched a special program on rice in Nepal with the main aim of import substitution. The program, named as Mega Rice Production Program (Brihattar Dhan Utpadan Karyakram), led by Crop Development Directorate of Department of Agriculture during the first phase, were launched in 13 districts of five clusters namely; Jhapa, Morang and Sunsari under Eastern cluster, Sarlahi, Bara and Parsa under Central cluster, Rupandehi and Kapilvastu under Western cluster, Dang, Banke and Bardiya under Mid-West cluster and Kalali and Kanchanpur under Far-west cluster. The MRPP focused on two components: increasing productivity of main season rice and increasing area and productivity of spring season rice (DoA, 2015).

2.6.3 Agricultural perspective plan (APP 1995-2015)

The Agricultural Perspective Plan had been developed by the government of Nepal to obtain economic development, poverty reduction, and food security through agricultural development. The key aspect of APP is to accelerate agricultural growth through increased agricultural production, poverty alleviation through employment opportunities in the agricultural sector, transforming Nepal from subsistence agriculture to commercial agriculture, agricultural development for overall economic transformation and food security throughout Nepal and to develop strategies, plans and programs to prepare Nepal for future food needs (APP, 1995).

Chapter 3: Methods

3.1 Research Design

A research design is the blueprint that contains the transformation of the research question into a workable and logical framework of strategies and methods to ensure effective and systematic answers to these research questions (Bryman, 2016). Choosing specific strategies and methods to conduct research is closely connected to how the research questions have been developed. To put it in other words, research design connects the objectives of a study to a suitable method of data collection, measurement of data, and how they are analyzed.

The research design used in this research is qualitative in nature. Qualitative research is a type of research conducted to understand the process by which events and actions take place. Although, this does not mean that qualitative research is unconcerned about the outcomes. One major strength of qualitative research is understanding the process leading to the outcomes. Processes that experimental and survey research often fails to identify (Maxwell, 2012). While, quantitative data includes closed-ended information, gathered through rating scales, checklists, questionnaires, etc. where these data are statistically analyzed, qualitative data consists of open-ended information which is gathered through interviews, focus group discussions, and observations. The analysis of qualitative data is conducted by analyzing words, texts, and behaviors and further accumulating them into categories, and developing patterns analyzing diverse ideas and theories (Kroll & Neri, 2009).

3.2 Study area and setting

Since this study is primarily based on secondary data, the data collection site, and setting cannot be established. However, this research has focused on the literature on SRI from Nepal and the experts who have been engaged in disseminating knowledge and practice of SRI in Nepal.

3.3 Sampling

Sampling does not only limit the sampling of people but also applies in the case of documents (Bryman, 2016). The unit of analysis for the research is the artifacts (documents, research papers, reports, scholarly articles) having direct reference to the research questions.

The pre-defined inclusion criteria for a sampling of documents in this study was to filter available artifacts on the basis of their relevance to SRI experiences in Nepal. In cases where enough artifacts were not available due to certain limitations (elaborated in the respective section), artifacts were derived from similar settings such as experiences of SRI in developing nations and SRI adoption cases in India.

Through purposive sampling, experts on SRI in Nepal were identified. To be more specific, opportunistic sampling was conducted to gather information from the key informants. Opportunistic sampling entails the capitalization of opportunities to collect data from certain informants, whose information and expertise provide data relevant to the research question (Bryman, 2016). Contacts were built from the target population of experts and the ones available and willing to share their knowledge and experiences took part in the study as key informants.

The number of sampling units for the primary data collection is two. Two experts in the field of SRI namely Dr. Rajendra Uprety and Mr. Ram Khadka. Dr. Rajendra is the Division Chief, Food security and agribusiness Promotion Division at Ministry of Land Management, who has been engaged as extension officer involving SRI since 2003. Mr. Ram Khadka, who had been working as a plant scientist at National Agricultural Research Council**.** Data concerning the number of sampling units for secondary data collection could not be recorded because a wide range of documents were reviewed.

3.4 Data collection

The data required for this research were extracted through secondary sources as well as from primary sources. Primary sources of data can be described as original data sources, where the data is collected by the researcher to suit his/her specific purpose of the study. The primary sources for the study were the experts who were interviewed. Secondary sources of data were documents that had not been produced by the researcher, but the focus of the documents contributes to providing relevant data required to conduct the research (Bryman, 2016).

The fundamental source of data required for this research was extracted from the SRI International Network and Research Center. The SRI International Network and Research Center were established at Cornell University in 2010 in response to the increasing importance of the SRI containing a large number of published literatures on SRI (SRI International Network and Resources Center, 2018). Moreover, published printed sources, books, journals, newspaper articles, websites, unpublished records, government records, reports published by international organizations related to SRI were searched through various online platforms and purposely chosen to collect relevant data required to conduct this research.

An interview guide was used as a tool to collect primary data from the key informants i.e., the experts in the field of SRI engaged in Nepal. A semi-structured interview design was followed where the researcher had a list of specific questions to be addressed to get answers to the research questions. However, the informants had a leeway in the process of replying to these questions. Semi-structured interviews were chosen because the questions cannot always be followed as prepared in the interview guide, and the researcher can pick up on topics that come up during the interview to get better information about the topic that interests them in relation to the study. The interview process is quite flexible in the semi-structured interview. Additionally, it also helps to make the researcher understand how the interviewee perceives certain issues, what they find important and how they explain the occurrence and pattern of certain events, patterns of behavior (Bryman, 2016), which in this study was very necessary to do so. Because, it helped the researcher get a better understanding of the context of the farmers from the agricultural extension officers' point of view who have been engaged in disseminating knowledge and practice of SRI in Nepal for quite a period of time.

3.5 Analysis

To conduct the analysis of qualitative data, thematic analysis was conducted. Thematic analysis is the most common method of conducting analysis for qualitative data. The themes are motifs that are identified by reading and rereading transcripts or notes that help to extract meaning and context through the data. While conducting thematic analysis, it is essential to reflect on the research questions while reading the documents to generate codes. These codes contribute to establish link and continuities within the data thus themes are identified (Bryman, 2016).

First focusing on the research questions, pre- coding was done consisting of pre-codes that may be identified in the documents and transcripts obtained through secondary and primary data collection respectively. Further, after continuous reading and re-reading codes were identified and through continuous brainstorming, codes were classified into multiple categories leading to the formulation of themes.

3.6 Limitations and ethical considerations

Some of the limitations of qualitative research is that qualitative research can sometimes be too subjective. Subjective in a sense that the research findings mostly rely on researchers' views and understanding regarding the context of the research (Bryman, 2016). Furthermore, qualitative research where findings are often driven by researchers' views and understanding is almost impossible to replicate as the research is often unstructured and reliant upon the researcher's ingenuity (Bryman, 2016).

Secondary data source as the data source does have its own drawbacks. Despite being time and cost-effective, the secondary sources are often claimed to become obsolete because the data available might not serve to fulfill the overall objectives of a particular research (Sekaran, 2016). Therefore, it is important to ensure that the data sources chosen must provide updated information. Secondary data sources can be used to conduct a detailed exploration of existing research data, but it also carries ethical issues which should be taken care of. Since there are various platforms that provide information such as the internet, books, or another forum, there is a question of permission for re-use and analysis. In such cases, the authors/owners of the original data were acknowledged, and credible research works were referenced to.

3.7 Reliability and validity

Reliability and validity are the most prominent criteria to evaluate the quality of a social research. Reliability of a research concerns the criteria of consistency of a measure, meaning that if the results of the study will be consistently repeatable. Reliability in qualitative analysis of secondary data can be hindered because the researcher might lack an insider's understanding and knowledge of the social context where the data was produced (Bryman, 2016). Thus, as this research is based on qualitative analysis of secondary data, this issue might have caused misinterpretations of data and weakened its reliability. The coding approach to qualitative data analysis is also criticized because there is a possibility of losing the context of what was said because coding consists of picking chunks of text out of the main context (Bryman, 2016).

Validity, in many ways, is the most important criteria to measure the quality of a research. It refers to the accuracy and the integrity of the results that a study intended to measure. If a study has a high level of validity, then it means that the results produced by the study are consistent with the real-world characteristics and variations of the social and physical world (Bryman, 2016).

Referring to the contextual validity of qualitative study, the qualitative aspect of the study was carried out through data collection of secondary as well as primary data. It concerns threats such as inadequate or based knowledge of prior studies. The researchers' positionality of prior studies might hinder the achievement of high level of validity. Risks from the researcher's side such as observer-caused effect, observer bias, and researcher bias in this study were controlled through a review of the results with the informants of the data. Other risks such as limited access to data, complexities of the human mind, lack of validity of settings and events as described by Maxwell (2012), are some of the factors that has affected the results of the study in a limited scale due to physical restriction of data collection in Nepal.

3.8 Conceptual framework

3.8.1 Sustainable Intensification

There has been a dire need of a resolution to global ecological and social challenges which calls for nutrition sensitive, climate smart and low carbon-based agricultural systems. The aspiration to develop productive agricultural systems with minimal environmental harm, and to build natural and social assets calls for a wide range of sustainable agriculture methods (Pretty & Bharucha, 2014). Sustainable production systems are characterized by the following factors, if (1) utilize productive crop varieties and livestock breeds which can utilize external as well as local inputs; (2) avoid the unnecessary use of external inputs; (3) harness agro-ecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism; (4) minimize use of technologies or practices that have adverse impacts on the environment and human health; (5) make productive use of human capital through knowledge and capacity building to adapt and innovate; make productive use of social capital to resolve common issues for example water irrigation, pest management, improving soil quality; and (6) minimize the impacts of system management on externalities such as GHG emissions, clean water, carbon sequestration, biodiversity, and dispersal of pests, pathogens and weeds (Baulcombe, Crute, Davies, Dunwell, Gale, Jones, & Toulmin, 2009). Sustainable Intensification is therefore not only exclusive to a specific agricultural system but entails principles of sustainable agricultural systems (Bell, 2016).

The success of SRI heavily depends on proper policies and proper infrastructure that both push and pull farmers towards such sustainable practices (Reardon, Barrett, Kelly, &

Savadogo 1999; Garnett et al., 2013 as cited in Bell, 2016). Sustainable Intensification practices have generated outstanding results in many rice producing areas, Pretty, Toulmin, and Williams (2011) reported that from 40 projects over 20 countries that involved over 10 million farmers, the application of SRI resulted in increased farm productivity by at least two-fold, and alongside minimized costs and emissions. Sustainable intensification systems such as SRI are not only an efficient as well as sustainable technique of rice production, but also have implications to the food security dimension of a country. Tilman, Balzer, Hill, & Befort (2011) emphasized that implementation of sustainable intensification around the world could help us meet the food demand by the year 2050.

3.8.2 Agriculture Innovation System (AIS) approach:

AIS is "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance," (Hall, Janssen, Pehu, & Rajalahti, 2006). AIS does not focus on one thing, but is a dynamic process that recognizes how different agents interact, share, access, exchange and use knowledge. It emphasizes the mere need for interactions throughout the value chain beyond the farm gate i.e., people, linkages, infrastructure, and institutions (Klerkx, Aarts, & Leeuwis, 2010). Experts such as Gervacio (2012) and Temel, Janssen, & Karimov (2002) have defined AIS as "set of agents (i.e. Farm organizations, input supply, processing and marketing enterprises, research and education institutions; credit institution, extension and information units, private consultancy firms, international development agencies and the government) that contribute jointly to the development, diffusion and use of new agricultural technologies, and who influence, directly or indirectly the process of technological change in agriculture". In simple words, it is a system that does not only deal strictly with the innovation itself but is interconnected among its social, institutional, economic, and technical features. This system recognizes the role of dynamic cadre of actors who provide technology development as well as the transfer, adoption, and adaptation and for promoting knowledge for the betterment of performance of this system as a whole.

3.8.2.1 Relevance of Agriculture Innovation System Approach

Low-income countries have a dire need for agricultural innovations and technologies. In the current situation where the availability of agricultural land is decreasing the ideal situation is to increase productivity of the limited land. New agricultural innovation and technologies not only help these countries tackle poverty, but also meet the rising demands for food, at the same time tackle the adverse effects of climate change. But the results have varied across regions and the benefits have been distributed unevenly, because of various factors; organizational capacities, institutional and policy environments, socio-cultural factors, and demand for food and agricultural products (Meyer, 2009). Therefore, it is vital to recognize agricultural innovation as a process that involves many factors and actors (as well as their interaction) that shapes its adoption by the farmers.

8.8.3 Adoption and Diffusion Theory

Adoption can be defined as 'the integration of new technology into an existing practice and advances forward through a period of trying and some extent of adaptation (Loevinsohn, Sumberg, Diagne, & Whitfield, 2013). As a psychological perspective, adoption can be described as a mental process where an individual gets through the first phase of hearing about an innovation to final utilization of it. It is further divided into two forms: rate of adoption and intensity of adoption. The rate of adoption is concerned with the relative speed with which the farmers adopt a new agricultural innovation whereas the intensity of adoption is concerned with the level of use of a new innovation (Bonabana-Wabbi, 2002).

Adoption of new agricultural innovation and technology is not an easy task because there are various factors that come into play. If the adoption process is moving forward at a slow pace, it means that there are some unforeseen factors that are influencing the adoption process. Concerning the constraints to adoption of agricultural innovations it has been well established that there are certain determinant factors such as the nature of the technology, awareness about the technology, risk aversion, institutional constraints, lack of human and financial capital and lack of infrastructure (Rogers, 2010).

In this context, adoption and diffusion theory can be used to determine the constraints that influence the principal users' decision to adopt or reject an innovation. Innovation is an idea or a practice that strikes as something new to the principal users i.e., farmers in this case. The decision-making process has five steps, which is defined as the innovation diffusion theory (IDT) (Rogers, 2010).

The first stage of IDT is the familiarization with new innovation where the principal user gets to know about the new innovation, how it functions and explores its purpose and the need to utilize it. The second stage concerns if the principal user likes or dislikes the new innovation.

Then, in the third stage the principal users decide whether they are willing to adopt the new innovation or reject it. The fourth stage occurs when the principal users perform the implementation of the new innovation and in the fifth stage, they confirm the decision whether to continue using the innovation or not (Rogers, 2010).

Rogers (2010) has identified five attributes that stimulate the likeability of the innovation to the principal user which affects their decision.

1. Relative advantage: the potential adopter compared the new innovation to their traditional technology
2. Compatibility: Where the potential adopter sees the new innovation consistent with the old ways, experience, needs and beliefs
3. Complexity: The potential user analyses the level of difficulty to adapt to the new innovation
4. Trialability: The potential user evaluates the degree to which the innovation can be adopted to use on a limited basis
5. Observability: The degree to which the outcomes of the new innovation is visible to oneself and others

3.8.3.1 Relevance of adoption and diffusion theory

Crop yields in developing countries have been low due to restricted adoption of new innovations such as the SRI. SRI is a knowledge-intensive rice farming technique that requires a crucial amount of local adaptation as well as managerial skills. Since, SRI fields differ from conventional rice farming systems, many unforeseen reasons for example social norms and conformity pressures may be discouraging adoption among the farmers.

Adoption of improved innovations and technologies as well as production practices are vital for driving agricultural development in countries like Nepal. Despite its potential for agricultural development, farmers have not been able to reach optimum levels of production in Nepal. Adopting new innovation such as SRI in contrast to conventional farming techniques which has been followed and then passed over to generations and generations of farmers is critical to meet the multi-dimensional goals in relation to environmental sustainability, efficiency, gainfulness as well as climate resilience (Kumar, Takeshima, Thapa, Adhikari, Saroj, Karkee, & Joshi, 2020)

In this context, adoption and diffusion theory can be used to determine factors that influence the principal users' decision to adopt or reject an innovation, in this study the innovation is the System of Rice Intensification. Through the application of adoption and diffusion theory, this study will focus on addressing the knowledge gap that persists in relation to the determinant factors that shape the adoption of SRI by the principal users i.e the farmers.

Chapter 4: Findings and Analysis

This section will present the results obtained through thematic analysis of available secondary data primarily, supported by primary data for the purpose of data validation and triangulation. Along with the findings are relevant quotes (in italics) by the experts that are presented in rectangular boxes.

4.1 Determinants of SRI adoption by farmers in Nepal

This section presents the findings based on the determining factors which shape SRI adoption in Nepal in five parts namely economic, demographic, technological socio-cultural and institutional factors.

4.1.1 Economic factors

In the case of adoption of new agricultural methodology, farm size plays a pivotal role. It has been widely discussed as one of the key determinant factors which influences the adoption of SRI. Numerous studies in Nepal have reported a positive relation between farm size and adoption of SRI (Sarwar & Goheer, 2007; Sigdel, Devkota, Joshi, & Devkota, 2014; Rana, 2015; Ghimire et. al, 2015; Suvedi, Ghimire, & Kaplowitz, 2017). For example, in a study conducted to study the determinants influencing the adoption of SRI among smallholder farmers, farm size positively influenced farmer's adoption of SRI (Kaloi, Isaboke, Onyari, & Njeru, 2021). The logical reason behind the positive relation between farm size and high rates of SRI adoption is that, the bigger the farm size the more the farmers are likely to adopt SRI since they can devote a small piece of land to try SRI. As farmers are skeptical about switching to a new rice growing technique, a growing pattern of farm size positively correlating to adoption of SRI was developed.

Another determinant factor for SRI adoption is family size. Farmers' family size is merely a reflection of labor availability. A larger household has the ability to provide labor in the field for the adoption of SRI, which implies that they can save the cost of laborers when compared to the traditional method. SRI methods are being quickly adopted by large farmers groups, because it contributes in saving labour demand, seed, investment as well as seeds (Meyer, 2009). SRI can also increase labour demand because of more weeding requirements. In the context of large-scale farms, more laborers are needed in nursery preparation, land leveling, and transplantation of young seedlings and weeding, for which farmers tend to hire additional laborers to practice SRI, especially in the phase of transplantation and harvesting. Basically, the labour need is dependent on the size of the farm (Rana, 2015; Ghimire et. al, 2015; Suvedi et. al, 2017; Varma, 2016). However, SRI is only labour-intensive in the initial stage. As farmers get familiar with the combination of techniques to produce rice with SRI, they master the process and overtime, SRI becomes a labour-saving methodology (Meyer, 2009). In many societies, farmers have been reviving the culture of *perma* (exchange of labor) which is a traditional labor exchange practice with the foundation of reciprocity amongst the farming communities (Rana, 2015).

Various studies have also focused on off-farm work as another determinant factor for the adoption of SRI (Rana, 2015; Ghimire et. al, 2015; Varma, 2016). In case the farmers are engaged in off-farm work and activities, they are more likely to adopt SRI compared to those who solely depend on farm activities for living. Off-farm activities are an important mechanism to deal with credit constraints which the farming communities face especially in developing countries like Nepal. These farmers who are engaged in off-farm activities do not spend their time conducting monotonous on-farm activities for living. Once they get out of the field and start getting more exposure, they also tend to have frequent access to information flow regarding SRI, which is very important in the process of adopting new agricultural technologies such as the SRI.

> *"Having multiple sources of income for farmers is always a benefit because these people are more willing to try out something new such as SRI without being hesitant. Especially when it comes to investing in mechanization for SRI, the farmers having the sole source of food or income are not willing to take a risk and adopt SRI."* -Rajendra Uprety

> *"The farmers at first are very hesitant when it comes to adoption of a new technology or a methodology. As a technician, when we demonstrate the technique of SRI the farmers do*

not seem happy because it completely contrasts their own technique of rice farming. Also, in the first phase of seedling plantation in the 25 cm gap, the field looks like a barren field, which gives them the impression that this new technique is not going to work. As a trainer, it is our job to take risks and show them the results so the adaptation of SRI spreads. Therefore, in such cases we have a contract with the farmers that they shall be paid back in case there is no/less production." -Ram Khadka

4.1.2 Demographic factors

Demographic characteristics such as the farmer's age, gender and their educational status are possible factors that influence the decision regarding adoption of SRI. The setting of farmers' households in Nepal placed different responsibilities among male and female members, which is quite common in the Nepalese society. However, this tendency might vary among different studies.

Farmer's gender is an important demographic factor where male-headed households are likely to adopt SRI. The tendency of male household heads to adopt SRI compared to the female counterparts is higher because male members relatively have more mobility and freedom to access information regarding agriculture (Karki, 2011; Rana; 2015; Gauchan, Panta, Gautam, & Nepali, 2012; Uprety, 2006).

"Male-dominance in the household decision making is one of socio-cultural characteristics of the majority of Nepalese households. Male members do have power over decision making in the household. So, it is very vital to target who to train. For example, in the indigenous Tharu community female members are the household heads and it is very vital to be able to convince the female household heads to adopt SRI. There are exceptions everywhere, but it is vital to conduct social scanning of the targeted area which can make the adoption process smoother." -Rajendra Uprety

The age of the household head also determines the farmers' SRI adoption behavior. However, there have been contrasting views regarding this factor influencing the adoption of SRI. Generally, the majority of the findings support that age negatively influences the adoption of the farmers. As the age of the farmers increase, there is also an increase in risk aversion with a decrease in interest regarding long term investment. On the other hand, young farmers are less risk-averse and have the will and energy to work for a promising outcome (Marenya & Bannet, 2007; Karki, 2011; Sigdel et. al, 2014; Rana; 2015; Suvedi et. al, 2017; Yokamo, 2020).

> *"The older the farmers are, the more accustomed they are to following their conventional rice farming techniques. While conducting trial sessions, we have noticed that there has been a clash between older and new generations of farmers debating over their trust and faith in this new technique. Generally, it is older generations who believe that their conventional technique which they have followed for generations produces the best results. It is only after they see the results in the trial fields, they tend to be inclined towards adopting SRI. The older farmers' experience however comes to our benefit when it comes to evaluating SRI after trials. Since they have decades of experience in rice production it is easier for these farmers to evaluate the benefits of SRI."* -Rajendra Uprety

Education status of the farmers' household head has been established as the most common factor that directly links to the farmers' adoption behavior. The more education the farmers have, the more they are open to try new technologies in agriculture and hence adopt SRI (Khadka et. al, Karki, 2011;Rana,2015; Gauchan et. al, 2012; Yokamo,2020).

4.1.3 Technological factors

Whether a new technology is to be adopted or not is based on a careful evaluation of multiple factors by the principal users. The nature or the characteristics of a new agricultural technique such as the System of Rice Intensification is vital to the process of adoption. If the technology is complex and hard to operate then it fails to attract the farmers (Doss & Morris, 2000; Uprety, 2010; Sigdel at. Al, 2014; Ghimire et. al, 2017; Khadka et. al, 2021). Furthermore, if a new agricultural technology like the SRI is perceived as being consistent with the farmers' needs as well as having a greater compatibility, they are likely to adopt SRI because they see it as a positive effect (Sigdel at. al, 2014; Yokamo, 2020). Similarly, increase in probability for adoption can be obtained through farmers' participation in trials and demonstrations of SRI conducted through extension services. In a study conducted by

Sigdel et. al (2014), SRI was introduced to 176 farmers but only 4.6 percent of the farmers adopted SRI. Failure to adopt SRI after trials were attributed to improper implementation of demonstration among other reasons.

Conducting transplantation with regular grid spacing and taking care of younger seedlings are one of the major challenges for scaling up SRI. In addition to that, labor shortages in the agricultural economy is an impediment to adoption of SRI despite projecting significant economic and ecological gains at least because of the fact that SRI requires more labor in certain phases. Therefore, introduction of mechanized means for transplantation can increase the adoption rate of SRI as it reduces the labor requirement (Uprety, 2006; Uprety, 2010; Khadka et. al, 2021)

Use of weeder in SRI fields in Morang   Picture credit- Nelson Pokharel, SRI network Nepal

Since Nepal is a developing country not all parts of the country have access to basic facilities such as transportation, schooling, water services and nearby markets. In such areas, the farmers generally lack access to agricultural equipment to conduct SRI such as weeder, tractor and transplanter (Uprety, 2005; Uprety, 2010; Rana, 2015). For example, in a study conducted by Rana (2015) in Lohasur, only a quarter of respondents had access to agricultural equipment. Lack of availability of agricultural equipment, low income from agriculture and lack of diversified sources of income had resulted in the farmers' inability to access agricultural equipment. Lack of proper technologies not only limit rice production but also the post-harvest phase. About 15 percent of the total produced rice is lost through spillage and grain loss in the post-harvesting process. The loss is attributed to pests, animals and inefficient rice milling (Tripathi et. Al, 2019).

> *"Manual weeding can be very expensive. Hired laborers cannot be trusted as they can be careless with their work. They often leave the roots of the weeds which causes the weed to regenerate within the following days"*- Rajendra Uprety

> *"Access and use of agricultural equipment are very necessary for encouraging adoption of SRI among the farmers. For example, we started introducing SRI in Kailali in 2008. We started transplanting and we were waiting to get our rotary weeder from India. It is very essential to use the rotary weeder between 15-20 days after transplantation. It took so long for us to get the rotary weeder. The weeds took over the field and we could barely see our rice plants. So, we opted for manual weeding, which is time consuming, hectic and expensive as well. Once the farmers found that they could not use rotary weeder they were already discouraged to adopt SRI, not because they did not believe in the technology because, lacked the capacity for weeding."* -Ram Khadka

4.1.4 Socio-cultural factors

The most significant socio-cultural factor that comes into play is the farmers' traditions connected to conventional farming. The farmers who have spent more years in farming are less likely to adopt SRI because they have been practicing conventional farming techniques their entire life. This socio-cultural tendency was also directly linked to the age of the farmers as well as the years spent in farming (using conventional rice farming techniques) (Karki, 2011; Rana; 2015; Suvedi et. al 2017; Ghimire et. al, 2017). Therefore, the findings indicated that the adoption of SRI decreases with the age of the farmers.

> *"One of the vital factors that results in rejection or disadoption of SRI among farmers who have seen the demonstration and even adopted SRI is that they realize that SRI is labor-*

intensive. But what they do not realize is that it is only tedious in the initial stages. For instance, while conducting transplantation of seedlings, there might be a single person who would previously conduct transplantation of conventional rice seedlings which is comparatively easier as there is no distance to be maintained and it does not have to be carefully planted. Therefore, farmers have reported that it's one of the reasons they do not adopt SRI'" Ram Khadka, NARC

Another important determinant factor is the level of commitment the farmers want to provide, SRI expert DR. Rajendra Uprety explains,

"*After the transplantation of seedlings within 15-20 days we need to conduct weeding of the field which is a bit labor-intensive. Given that there is no availability of weeder in the local market of Nepal, farmers are demotivated. Especially with the part-time farmers who use conventional methods, they are used to transplanting the seedlings and flooding their field which will take care of the weed and then leave for their labor work. Therefore, some farmers prefer conventional farming as they are well accustomed to it but do not realize that if they conduct SRI properly, they can get better results and would not have to provide labor half-time of the year if they could exploit this methodology."* Ram Khadka, NARC

4.1.5 Institutional factors

When the farmers have farm related issues, access to respective institutions such as the agriculture extension services plays a vital role in assisting them to find a possible solution. In case of adoption of SRI, extension services play a vital role because its accessibility reflects the service that helps disseminate necessary information to farmers so that they can stay updated regarding improved agricultural technologies (Gauchan et. al, 2012; Rana; 2015; Varma, 2016). This awareness developed through the interaction between farmers and the extension service officers enhances the adoption process of SRI. Through external agents, the farmers receive information regarding the whole process of SRI and are also trained to follow the methodology of SRI to get efficient results in rice production. These extension service officers have been often described as a "bridge" between the innovators of SRI and the principal users of SRI (Sigdel et. al, 2014; Rana, 2015). Another factor that can be closely connected to the provision and accessibility to extension services is information accessibility which determines the adoption of SRI.

Information access allows the farmers to familiarize themselves with SRI and its processes, which facilitates the process of adoption. Information access has played a vital role in the lives of farmers who have adopted SRI as it reduces the uncertainties about the performance of a purely new technology, transforming their assessment of SRI from purely subjective perspective to objective once information is shared (Sigdel et. al, 2012; Karki, 2011; Rana, 2015; Varma, 2016).

Access to road and transportation is also a determinant factor for the adoption of SRI (Sigdel et. al, 2014; Rana, 2015; Gauchan et. al, 2012). If the farmers have access to the nearest market, they can travel easily to buy agricultural equipment and more importantly they have a market where they can sell their produce. Access to road and transportation which enhances the market linkage provides the farmers the confidence to sell a demand-based commodity i.e. rice in the context of Nepal. Therefore, distance from the market negatively influences the decision of the farmers regarding SRI adoption. Poor accessibility to the nearby cities or market is also linked with the lower probability of the farmers to be involved in on-farm research and trials (Uprety, 2006; Sigdel et. al, 2014; Rana, 2015; Gauchan et. al, 2012; Uprety, 2016).

Further, farmers having access to good canal irrigation systems are more likely to adopt SRI. In areas where it is difficult for the farmers to access irrigation facilities, farmers struggle to manage water for irrigation (Dhital, 2011; Rana 2015; Uprety, 2016). For farmers having limited/no access to irrigation and experiencing erratic rainfall, the adoption of SRI is difficult. As SRI expert Mr. Ram Khadka puts it,

"*Ensured source of irrigation is one of the most important determinant factors of SRI adoption. Because if there is no source of water, no rice plant can survive. SRI does not require as much water for the conventional method. However, before the weeding, the fields are kept flooded with 5-10 cm water depth. If the field is not flooded with the given amount of water, the weeding cannot be done properly. Therefore, irrigation services are a must.*"

4.1.6 Geological factors

One of the recurring factors which determine the successful adoption of SRI in Nepal is related to water management. Water management process of alternate wetting and drying the soil until the soil cracks, is a very effective method but only limited to the areas having loose and friable soil or the soil having higher level of organic content. In areas with clayey soil, this method of alternative wetting and drying may negatively affect vegetative growth. When the soil is left to dry up to the stage of cracking, it becomes extremely hard, hindering the development of the plant's root and absorption of nutrients. However, under these circumstances, it is vital to adapt to the recommendations for different soil types (Uprety, 2006; Gauchan et. al, 2014; Uprety 2016).

> *"Adaptation of SRI is very difficult in areas having poor soil conditions. Research stations having poor soil conditions due to excess use of chemical fertilizers and/or lack/loss of organic matter in the soil, do not provide expected outcomes. In one way the soil becomes dead, which is called inert soil or sterilized soil. With the lack of organic matter, the microbes cannot survive, therefore in such areas where the soil is inert and suffers the lack of organic matter, adaptation of SRI is difficult as we cannot derive expected results in such conditions"* Ram Khadka, NARC

4.2 Comparative benefits to conventional methods and relevance to climate change

4.2.1 Greater drought resistance with reduced water requirements

One of the major priorities in rice research is saving water (Barker, Dawe, Tuong, Bhuiyan & Guerra, 1999), since irrigated rice is one of the largest sources of water consumption, SRI contributes to the reduction of water demand in agricultural production. Opposed to conventional rice production practices, SRI challenges the general notion that rice production performs best under flooded water conditions. SRI practices intermittent irrigation which supports vegetative growth to maintain moisture in order to avoid drought stress. Consequently, this technique results in water saving compared to continuous flooding in conventional farming (Dobermann, 2004; Hidayati, Triadiati, & Anans, 2018; Uprety, 2006; Uprety, 2016; Rana, 2015; Karki, 2011).

As per the 2011 National Agriculture Census of Nepal, only 53% of the total cultivated land has access to irrigation (CBS, 2011). However, a significant portion of this area has access to seasonal irrigation. As a result, rice crops in Nepal tend to face water shortages during some stages, or at worse the entire cycle, especially in rainfed drylands (Khadka et. al, 2021). In this context of Nepal, the system of rice intensification has prospects of being more accessible as well as affordable for poor and marginal farming households who face the problem of water scarcity. Many agricultural regions in Nepal suffer from decrease in rice productivity due to water unavailability followed by erratic rainfall (Dhital, 2011). Fields that are far from the irrigation source mostly have been converted to the rainfed (unirrigated) lands because of the unavailability of sufficient water in the streams. In this scenario, SRI provides a comparative advantage as a suitable method for rice cultivation as it thrives by using 30%-50% less irrigation water compared to the conventional rice farming methods (Styger & Uphoff, 2016). Adoption of SRI can lead to the use of the same amount of water to cultivate even larger areas of fields. Thus, larger areas can be brought into rice cultivation through SRI.

The Hindu-Kush region of Nepal, Bhutan and Sikkim is found to be the origin of arsenic contamination in South Asian countries, which puts the respective population in constant threat of arsenic contamination (Fendorf et. al, 2010; Khadka et. al, 2021). Therefore, in addition to being at risk of drinking contaminated water, the residents of these regions are at risk of consuming rice which is grown under flooded conditions which is another direct source of arsenic contamination. Accumulation of arsenic content in the water, results in reduction in yield as the arsenic matter makes the plants more vulnerable to certain diseases by boosting sterility in panicles. SRI uses a reduced amount of water through alternate wetting and drying (SRI). By encouraging farmers to keep their soil aerobic for a major portion of rice crop, it contributes to the reduction in arsenic contamination in rice produce (Wichelns, 2016).

"In the South-east Asian countries, the levels of arsenic in rice produced through conventional farming systems are quite high. Continuous flooding results in the absorption of arsenic from the soil, which further causes health impacts for example diseases related to stomach, kidneys, liver etc. There have also been findings related to SRI, through AWD which constitutes a promising means for reducing arsenic levels in rice." -Ram Khadka

4.2.2 Mitigation of Greenhouse Gas emissions

Rice paddies are one of the major sources of methane (CH_4) and nitrous oxide (N_2O) emissions (Vermeulen, Campbell, & Ingram, 2012). Therefore, it has gathered attention due to its significant contribution to global warming. Rice fields are the main source of methane (CH_4) in the agricultural sector, and the world rice acreage is 162.06 million hectares (2019) (Shahbandeh, 2021). Methane (CH_4) emissions from these rice fields are generated because of the flooded soil conditions where the methanogenic bacterias thrive. Therefore, switching paddy soils from anaerobic to aerobic status can eventually result in reduction of methane emissions. Switching to aerobic soil conditions could on other hand increase emissions of nitrous oxide (N_2O) by aerobic bacteria. A single nitrous-oxide(N_2O) molecule can contribute about 12 times more to climate change compared to methane (Andrea, 2018). Although, no studies so far have shown that nitrous-oxide (N_2O) increases offsetting the gains from methane (CH_4) reduction (Styger & Uphoff, 2016).

However, there have been studies which have shown that SRI could indeed make a net contribution for reducing greenhouse gas emissions. A study by Karki (2010), which was conducted in the terai region of Nepal measured methane and nitrous oxide emissions from two comparable paddy fields (one with SRI and other with conventional farming methods). The study reported that methane (CH_4) emissions were reduced by four-fold in SRI fields, whereas nitrous-oxide (N_2O) was reduced by five-folds. These results were derived due to the reduction in inorganic nitrogen. It has also been attributed to the rhizospheres being more effective 'sinks' for nitrogen in the soil (Rana, 2015).

Methane (CH_4) emission through rice production is reduced between 22% to 64% through intermittent irrigation or alternate wetting and drying processes (Jain et al. 2014; Dill et al. 2013; Dahal, 2014; Raut et. al, 2020). When it comes to nitrous oxide (N_2O) emissions, it is found to increase slightly with the application of SRI, and sometimes also to decrease with the decrease in use of fertilizers (Kumar et al. 2007; Visalakshmi et al. 2014; Thakur et. al, 2016; Raut et. al, 2020; Uphoff, 2014). Use of less fertilizers and lesser agrochemicals contributes to the reduction of rice production's carbon footprint.

Greenhouse gas emissions from producing, distributing, and using the lesser inputs equals to about 5-10% of the global warming potential (GWP) from all emissions derived from food production (Vermeulen et. al, 2012). In that scenario, rice-paddies grown from SRI methods can help reduce global warming potential (GWP) by 20-30% at least, and at most have been successful to reduce the GWP by 73% (Styger & Uphoff, 2016). In another study conducted by Jain et. al (2014), it was found that with SRI production management, they derived 62% reduction in methane (CH_4) emission whereas on the other hand it was accompanied by 25% increase in Nitrous oxide (N_2O), which gave a net overall reduction of 28% in global warming potential (GWP).

"When there is continuous flooding, the population of anaerobic microbes increases and produces methane in the case of traditional rice farming. SRI changes that environment of continuously flooded fields to AWD which changes the setting of the rice production, resulting in reduction in production of methane (CH_4). On the other hand, due to the non-flooded irrigation process of SRI, it results in production of nitrous oxide (N_2O) compared to the traditional rice farming system. However, when we calculate the net results of the reduction of methane and production of nitrous oxide, we can conclude that it contributes to a net reduction of greenhouse gases emissions." -Ram Khadka

[Global warming potential (GWP) is defined as the cumulative radiative forcing, both direct and indirect effects, over a specified time horizon resulting from the emission of a unit mass of gas related to some reference gas [CO2: (IPCC, 1996)]. *

4.2.3 Resistance to rain and wind

Through the comparative study of SRI and conventional cropping systems, the differences were derived from the stage of tillering. SRI has lower plant density resulting in developing a greater number of tillers compared to the conventional farming practices. SRI results have shown that the technical methods that SRI uses, helps to avoid the growth-limiting factors such as transplanting stress when older seedlings are used in conventional methods (Laulanié,1993; Serpantié et al., 2013; Gbenou et. al, 2016: Uprety, 2016). As these plants have thicker tillers as well as deeper roots, also since they are widely spaced, it is found that these plants resist heavy rain and winds. Bigger and stronger root systems not only make the plants resistant to drought, rain, and wind, but also to cold spells (Sudhakar & Reddy, 2007; Uphoff, 2006). For example, in a study conducted by Chapagain et. al, (2011), during an incidence of storm, only 10% of the SRI field lodged when the storm struck, compared to the

55% lodge of conventionally managed rice fields. It has been established that the percentage of plant lodging can be significantly reduced by using intermittent irrigation as compared to the continuously flooded younger seedlings with wider spacing (Chapagain et. al, 2011).

4.2.4 Higher disease and pest resistance

Many insect pests and microbial pathogens are likely to become rampant with global warming (Styger & Uphoff, 2016). In SRI, the plant density is low. The reduced plant density reduces humidity in the canopy since the air can easily circulate through the plants. This setting provides a disadvantageous environment for the pests and diseases compared to the constantly water flooded rice paddy fields (Karthikeyan et al. 2010; Kumar et al. 2007; Visalakshmi et al. 2014; Gbenou et. al, 2016). It has also been reported that there is a tendency of significant drop in the use of agrochemicals by the farmers adopting SRI because of its high disease and pest resistance (Karki, 2010; Chapagain et. al, 2011; Rana, 2015; Andrea, 2018).

4.2.5 Soil enhancement

Conventional farming methods intensively use inorganic sources of nutrients in anaerobic soil to increase rice yields. In contrast to that practice, SRI application has empirically established that, by managing and mobilizing the elements within the atmosphere such as nitrogen, carbon, and oxygen and the nutrients within the soil (phosphorus, potassium and micronutrients) more successful results can be derived (Uphoff & Kassam, 2009; Ceesay, Reid, Fernandes, & Uphoff, 2006; Dobermann, 2004). The SRI techniques enhance soil fertility, and consequently improve the soil health as well as the productive capacity. By adding organic matter to the soil, it induces root growth both in the level of greater depths as well as having more complex branched root systems that reflects the resistance to uprooting (Uphoff & Kassam 2009; Karki, 2011). SRI enables the enrichment and improvement of soil through organic matter, which in fact is one of the four principles of SRI. As soils are enriched and improved due to the addition of organic matter, nutrients become available to the plant from the organic matter. Farmers, who have been constantly using chemical fertilizers on their land have faced stagnation, followed by decrease in rice productivity which is attributed to soil's decreasing fertility (Khadka et. al, 2021).

"By promoting the use of organic matter, SRI enhances the soil conditions. Moisture plays a vital role in the development of fungal diseases. As there is distance between the plants, it gets sufficient nutrients for example, air and water and sunlight. So, when there is space between the plants, solar radiation penetrates deeply, and makes the soil dry, which is necessary for AWD in SRI." -Ram Khadka

4.2.6 Crop cycle duration

SRI reduces the crop cycle with an average reduction of 14 days and at the same time providing higher yields (Uprety, 2006; Uprety 2010; Uprety, 2016; Rana, 2015; Karki, 2011; Gbenou et. al, 2016). The reduction in crop cycle results from early transplantation, stimulation of plant's metabolism and greater healthy root development . Reduction of crop cycle also contributes to reduction of risks related to hydro-climatic hazards and can also affect the crops' exposure to pests and diseases (Uphoff, 2007; Meyer, 2009; Styger, Attaher, Guindo, Ibrahim, Diaty, Abba, & Traore, 2011). One of the most detailed assessments regarding the crop cycles has been conducted by the District Agricultural Development Office, Morang, Nepal where eight varieties of rice were cultivated. On average, they matured 16 days sooner, compared to the conventional rice. For the 413 farmers, the yield produced from SRI was 6.3 t/ha whereas the ones that were grown with the traditional method had yields of 3.1 t/ha (Uphoff, 2006). It projects that SRI provided double yield in lesser time. Shorter crop cycles further enhance many other benefits. For example, since the crop cycle is short and we can get rice in a shorter time, the field now can be used for a short-season crop for example a vegetable or a following crop such as wheat. Shorter crop cycle also means less water requirements. This phenotypic change in SRI can be relevant as a coping mechanism to reduce climate stress. The shorter crop cycle also protects the plant from getting exposed to any biotic and abiotic stresses, which is more likely to increase with global warming.

4.2.7 Yield increase

SRI results in Morang. Farmers predicted over 8 tons yield after application of SRI to their field.
Picture credit: Rajendra Uprety

The traditional rice production system has no capacity to explore the natural potential of the rice plant. Since, it has been transplanted with old seedlings, with less space and continuous flooding which holds back the rice plant's natural potential (Tripathi et. al, 2016). Some studies have also established that SRI methods enhance physiological and morphological changes in rice plants which further improves the yields and increase factor productivity (Huizhe et al., 2006; Vijayakumar et al., 2006; Thakur et al., 2010). SRI techniques have increased grain yield with benefits to both subsistence and commercial farmers (Rana, 2015; Uprety, 2006; Uprety, 2016, Karki, 2011). For example, in a study conducted by Uprety (2008), over five years (2003-2007) the average yield produced by SRI was 7.5 t/ha whereas the yield produced by conventional methods only produces an average of 3.5 t/ha in Morang district of Nepal.

4.2.8 Reduced use of seeds and agrochemicals

Most farmers, with no understanding of how they can produce more with less (clashing with the conventional system which they are accustomed to), have found it hard to process and believe that SRI methods by using seed rate of only 10% (average) of what they used for conventional farming, can give them double yield in the most favorable conditions (Tripathi et. al, 2016; WWF, 2007; Uprety, 2016; Rana, 2015). Since, SRI reduces the seed requirements by 80%-90%, it cuts off the cost of hybrid seeds for the farmers as well (Uprety, 2005). Similarly, in a study conducted by Uprety (2005) in Morang district, once SRI was introduced it resulted in saving 77,233 mt of seeds where previously 92,679 mt seeds were required. This indicates that only 16% of the allocated seeds for conventional farming was used to farm on 1545000 ha land (at the rate of 60kg/ha in conventional method). All in all, since SRI reduces seed requirements by approximately 80-90 percent, it saves the cost especially with the hybrid seeds (Uprety, 2005; Satyanarayana et. al, 2004; Khadka et. al, 2021).

"As the price of seeds are increasing, especially hybrid seeds, SRI plays a very efficient role in the use of seeds. Compared to conventional rice farming which uses 45-50 kgs of seed per hectare, SRI methodology efficiently uses 4-6kg of seeds for cultivation. Especially in the context of Nepal considering the backgrounds of an average farmer, using 4-6kg of seeds per hectare instead of 45-50 kgs plays a huge role in the adoption behavior of the farmers. This also implies that the demand for imported seeds is also reduced to some extent." -Ram Khadka

"Saving seed costs of about 90% of prior seed needs is a great encouraging factor that attracts the farmers. Especially for the resource-constrained farmers for whom these savings can be a significant contribution to their household food security. Since most of the grains from preceding yield are already consumed, as planting time arrives, most of these households are facing critical food insecurity. The time between May-September is the harshest period for vulnerable groups in Nepal. Therefore, in this context it is best to opt for a management practice which reduces costs as well as gives benefit to food-insecure households such as the system of rice intensification" -Rajendra Uprety

Since, SRI plants have higher resistance to pests and diseases, the requirement of toxic agrochemicals is reduced. SRI methodology also suggests the use of organic matter rather than chemical matter to enrich the soil quality. Hence, since SRI uses fewer agrochemicals, it results in reduction in accumulation of these substances in water as well as soil systems. It is a blessing for both human health as well as ecosystem health (Andrea, 2018; Raut et. al, 2020).

4.3 Determinant factors for farmers' adoption: AIS approach

Nepal's major crop is rice which contributes to more than 50 percent of Nepal's total food consumption (Basnet, 2021). Therefore, achieving rice security is a significant step towards achieving food security in Nepal. Not only does the national food security depend on rice production, but the national economy itself is dependent on rice production. For example, The GDP growth of Nepal in the fiscal year 2018-2019 was 7.1 percent, where the share of rice in Nepal's agricultural GDP was 21 percent and 7 percent in the national GDP (International Monetary Fund, 2019).

Although the rice production in Nepal has grown by 2.2 times since 1961-1963 to 2010-2012 with 2.1 million tonnes to 4.68 trillion tons respectively. However, within the same period, the annual increase in rice production was 1.8 percent compared to the population increase rate of 2.3 percent (Tripathi, Bhandari & Ladha, 2019). The rice self-sufficiency ratio remains lower than 100 (Tripathi et. al, 2019), which implies that in order to fulfil the domestic demand of rice, it needs to be imported. Farmers' adoption of SRI will shape the future of agriculture in Nepal.

From the findings of this research, the economic factors that influence the adoption behavior of the farmers in Nepal are influenced by farm-size, the family-size and off-farm income. However, adoption behavior is mainly influenced by family size, which is a reflection of labor availability. Labor scarcity is a rising constraint in Nepal since the farm wage rates in the last decade has increased by 4 times from Rs. 75/day in 2003 to Rs. 290/day in 2013 (Ghimire et. Al, 2019). Since SRI is labor intensive in the initial phases, farmers analyze the level of difficulty to adapt this new innovation i.e SRI. As these farmers have been practicing traditional rice cultivation, they may view the new innovation as inconsistent with their old ways, experiences and needs (Rogers, 2014). As both large-land and small-land holders have been associated with the adoption of SRI, the decision is mostly dependent on availability as well as commitment of labor to the field. As discussed by Dr. Uprety, the level of commitment to carefully learn the techniques as well as implementation is another factor beyond availability of labor. However, labor demand can be minimized through mechanization of SRI which is yet another technological determinant factor which further can be linked to the institutional aspect as well.

To achieve wider uptake of SRI, SRI should be mechanized. Examples include the introduction of motorized weeders, power tillers, tractors and mechanized means for careful transplantation of young seedlings. By using power tillers and tractors for preparing and leveling the fields, adopting mechanized weeders and harvesters we can make SRI an attractive package by saving time and cutting costs. However, since the availability and accessibility of these machinery is dependent on other factors. As Dr. Uprety implies,

> *"India has an industry which provides a wide variety of advanced agricultural equipment. They produce it in large quantities and sell it locally for cheap prices. However, it is not the same in Nepal as we do not have our own production of these equipment. For a weeder that costs Rs, 400 in India, the same weeder once it is imported to Nepal, costs Rs. 2000. First of all, these equipment are not available to most of the agricultural farmers. Secondly, their low purchasing power reduces accessibility in Nepal."*

In such a context, it is vital to assess the machinery needs of the farmers. Furthermore, Dr. Uprety suggests that, "conducting socio-technological adaptation" is an alternative solution which he has witnessed around various farming communities in Nepal where they create their own local version of machinery.

The role of research and extension services is vital in any nation to promote development of agriculture. In fact, the influence of extension agents can counterbalance the negative effect of lack of years of formal education (Bonabana-Wabbi, J. (2002). As a large percent of Nepal's economy is dependent on agriculture, it is important to direct appropriate amount of resources and develop policies towards production of quality food at reasonable/affordable prices for all; conservation of agricultural environment; sustainability of food security, agricultural, and rural development by promoting the application of environment-friendly techniques and technologies (Contado, 1997). When it comes to research, the investment in rice research is very low with 0.1 percent of the value of rice output being invested in rice research (Ghimire et. Al, 2019). The rice research program under the National Agricultural Research Council (NARC) receives only 4 percent of the total research budget allocated

(Ghimire et. Al, 2019). Limited resources leading to inadequate technical capacity has constrained NARC to conduct and effectively coordinate research and strengthen its bond with local research centers as well as in the international community.

The extension services in Nepal is dominated by government services with minimal representation from the private and non-profit sector (Ghimire et. Al, 2021). There is therefore a need for more representation in the extension services from the private and non-profit sector. As the public extension services results in inefficiency and lack of impact; poorly motivated workers; lack of incentives; top-down approach; no accountability to farmers; miscommunication of information; lack of supervision; no in-service training; and so on (Haug, 1999), there is a need to induce organizational diversification resulting in initiation of multiple sources of extension service provision. As farmers perceive research and extension as important in relation to development of know-how, increase efficiency, productivity, profitability and contribution for the overall wellness of their community as a whole (Oladele, 2011), it is a vital tool to engage the farmers as well as the other stakeholders in agricultural innovation adoption process simplify sentence.

The Agriculture Perspective Plan has focused on irrigation as one of the priority inputs for agriculture with high investment and long lead time in large surface irrigation. However, since Nepal is gifted with a rich endowment of rich groundwater resources, groundwater irrigation is more suitable as it provides opportunities to develop cost-effective solutions in a shorter lead time. For example, shallow tube wells bear comparative advantages as it requires low capital, low lead time and a quick return to investment (Bhandari & Pandey, 2006). There is therefore a need to boost investment in irrigation particularly groundwater irrigation.

"To achieve the objective of self-sufficient rice production, the Ministry of Agricultural Development has launched a mega rice production program (MRPP) which promotes the use of mechanical weeder and row/line plantation by distributing the required equipment to the farmers is currently being carried out in Nepal."

As explained by Dr. Uprety. As the Division Chief, Food security and agribusiness Promotion Division at Ministry of Land Management, who has been engaged as extension officer involving SRI since 2003, he believes that there is no such concrete thing as adoption or disadoption. He added, *"SRI is not a set of rules that has to be followed from A to Z. Out of its principles, even if the farmers apply two or three of its principles then they can get higher yield and keep practicing as it suits them. This is what I like to call Technology Hybridization where partial package integration is conducted and that is exactly what is happening with SRI in Nepal."*

Nepal in almost all of its development plans has included agriculture as a priority sector (at least on paper) although until recently the budget has been inadequate to fulfil the planned programs. The development plans have been found to design many agriculture related policies, strategies in Nepal. But in practice, it has lacked effective implementation, regular monitoring, and evaluation of these policies (Ghimire et. Al, 2021).

The concept of Agriculture Innovation System (AIS) has a significant association with extension and advisory services (World Bank, 2008). When a new technology is developed it is bound to interact with society. So when a technology such as SRI is introduced to society, the process from introduction to adoption is not a linear process. It is further dependent on numerous other factors. Therefore, there is a requirement in the shift in perspective of simply transfer of technology towards an Agricultural Innovation spectrum. This research highlights the weak links in this process of AIS which provides a better understanding of which stakeholders can play an effective role to scale up SRI to a wider extent. As a country which used to export rice in the past, has now been importing rice amounting to one million ton (Tripathi et. Al, 2019), and with upcoming time the problem will become only more serious. Rice yields should increase by 3 percent annually if Nepal aims to become self-sufficient in the two-three decades (Tripathi et. Al, 2019). This is a challenging task for the policymakers and researchers. Through investment on the research and extension, initiatives that promote mechanization and irrigation services in the agricultural sector, well-planned trails and training of SRI, it is possible to promote adoption of SRI. It can also include partial adoption i.e technology hybridization as suited to the principal user which will help us achieve self-sufficiency when it comes to production of rice. Also, to enhance active participation of farmers and awareness of SRI techniques and principles among farmers, media plays a vital role to expand the adoption of SRI in developing countries like Nepal. The role of effective communication to disseminate knowledge to the farmers, organizations, and policymakers reflect the importance of the media to disseminate knowledge about innovation such as SRI.

4.4 SRI as a means of sustainable agriculture in Nepal

SRI challenges the well rooted perception that rice performs best under flooded conditions. By making alterations to the long standing rice growing techniques so that the farmers resist the counterproductive continuous flooding technique of rice production has both economic and ecological benefits. SRI has numerous benefits over the conventional farming system such as reduced water requirements and hence greater drought resistance, reduction in arsenic content in water, soil enhancement, reduction in greenhouse gas emission, resistance to wind and rain, higher disease and pest resistance, shorter crop cycle, higher yields, reduced use of agrochemicals and seeds. By minimizing the demand of water in rice production, and also reducing the use of agrochemical inputs, farmers are able to achieve higher yields despite changing climatic conditions. By expanding the biological and economic productivity of land, labor, capital and water simultaneously this methodology has enabled the farmers to produce more output with lesser inputs by mobilizing the services and benefits of soil biota (Meyer, 2009). With its own set of costs and constraints, SRI has the following advantages by a) sustainably increasing rice production due to more tillering and better grain quality, b) minimizing the use of water is beneficial, particularly in water limited environments, and c) reducing GHG emissions.

As the impacts of climate change are already being experienced in Nepal such as increase in average temperatures, change in rainfall patterns, rise in the frequency of extreme weather events. Observed changes in climate in Nepal include more severe droughts and floods and shifts in agricultural seasons across different agro-ecological zones of Nepal. Agriculture is the cornerstone of the Nepalese economy, which contributes to one third of the total GDP of the nation. About 66 percent of the population is engaged in this sector (World Bank, 2019). However, inadequate production of key crops such as maize and rice to meet domestic demand is the reason behind the high import rates of staple crops. The slow development of the agricultural sector has been attributed to unfavorable weather conditions, insufficient irrigation services, lack of agricultural inputs such as seeds and fertilizers. Therefore, Nepal is in need of a major transformation in the farming practices with better ecosystem management. To make this possible, a supportive institutional and policy environment is needed. A conducive policy environment which gathers the economic, environmental and agricultural frontier with unconventional arrangements is necessary. In such a context, SRI can contribute to sustainably by increasing crop productivity, building resilience to climate change impacts and greenhouse emissions. However, SRI might not be the 'silver bullet' or as a 'universal solution'. It can be considered as a stepping stone towards development of new innovations and constant modifications and improvement (Thakur et. Al, 2016).

Chapter 5: Conclusion

One of the most evident and visible benefits of SRI is increase in yield. However, SRI is more about productivity of resources than yield and provides benefits beyond yield.SRI expands the biological and economic productivity of land, labor, capital and water all while buffering against the effects of climate change and reducing greenhouse gases (GHG). By minimizing the demand of water in rice production, and also reducing the use of agrochemical inputs, farmers are able to achieve higher yields despite changing climatic conditions. This methodology has enabled the farmers to produce more output with lesser inputs by mobilizing the services and benefits of soil biota. However, despite SRI increasing labor productivity in a sustainable manner, the labour requirement often hinders its adoption. Another major barrier to SRI adoption is that SRI is not suitable for areas having no irrigation source available. In such a context, mechanization of rice farming and development of irrigation infrastructure can shape a favourable setting for farmers struggling to tackle labor shortages or higher production, sustainably.

Chapter 6: Recommendation and Limitation

6.1 Recommendation

- Since the current agriculture research in Nepal is based on a top-down approach, the local priorities and demand are overlooked. SRI initiatives implemented in Nepal are driven mainly by NARC's research interests or commercial interests rather than addressing farmer's needs. In a scenario where farmers' SRI adoption behavior is negatively influenced by lack of agricultural equipment, researchers through a bottom- up approach can help develop equipment based on local resources and. Further, training can be provided to the local technicians who can develop appropriate equipment such as weeders and markers This can lower costs of such equipment.
- Furthermore, most SRI research is dominated by topics related to yield increase, performance of varieties and economic returns. In addition there is a necessity to

study reasons for adoption or non-adoption, farmer's perspectives on SRI adoption, farmers' adoption behavior towards new technology etc. from a social dimension. This will increase the understanding of why certain agricultural technologies are not being accepted. Thus, initiatives can be designed to promote SRI adoption.

- Similarly, as SRI increases the yields of rice varieties including premium rice varieties, suitable incentives should be provided to promote the production of premium rice varieties. Because of its higher quality, these premium rice varieties demand a higher market price. Therefore, the government can enhance the export of these organically produced aromatic rice varieties by providing incentives. Also, the government can conduct direct investment on transportation development and exploring the international market so that foreign currency can be earned through proper marketing of SRI products.
- Agricultural extension can emphasize participatory processes that involve the active participation of the farmers. Introducing new techniques such as SRI which reduces plant density and follow alternate wetting and drying rice might seem illogical to the conventional farmers at first. Therefore, it is necessary to involve farmers through farmer field schools, field demonstrations to achieve an active involvement of farmers for the successful implementation of sustainable agricultural practices like SRI.

6.2 Limitation

One of the major limitations of this study concerns the physical limitations caused due to the pandemic. As a new researcher in the field of SRI, I lacked first-hand exposure to the whole process of SRI dissemination and how the interaction between new innovations such as SRI and its principal users takes place. Hence, secondary data was the major source of data which leads to its own limitations. Lack of well recorded or published literature regarding SRI in Nepal was another constraint. Also, the referred documents may also have a bias toward favoring SRI.

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APPENDIX

Interview Guide

1. Would you like to share your name on the record, please?
2. For how long have you been engaged in the field of SRI in Nepal?
3. What is SRI? How is it different from traditional farming systems in Nepal?
4. In what ways is it beneficial compared to the traditional farming system?
5. How do the farmers perceive SRI when first introduced as a new innovation? How is their response?
6. As long as you have worked in this field, what would you say are the determining factors to adopt new technology such as the SRI?
7. Are there instances where the farmers first adopt SRI and in the long-term switch back to the traditional farming method? If yes, what are the reasons behind the switch-back?
8. What would be the major constraints that the farmers face whilst adopting SRI?
9. Do the farmers receive any kind of incentive from foreign donors or the Government of Nepal to promote the adoption of SRI? If yes, what kind of incentives?
10. From the three ecological terrains of Nepal i.e Terai, Hilly, and Himalayan, which terrain is the most suitable for the implementation of SRI?
11. What are the implications of SRI in the context of climate change in the context of Nepal?
12. What kind of assistance are received from GoN to implement SRI to a wide extent?
13. Is there a possibility that in the near future Nepal would export rice rather than import it to the international market?

14. What would you recommend can be done by the following to fully be able to utilize new technology such as SRI and make us a rice-based self-sufficient agricultural economy?

    a. Ministry of Agriculture and Livestock Development

    b. SRI professionals working in Nepal

    c. Farmers for self-sufficiency and commoditization of rice

    e. International Organizations engaged in SRI/ SRI Networks

16. Based on your experience, how far have we come along the process of disseminating knowledge and practices of SRI in Nepal?

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