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Status and measures of food insecurity in Karnali province of Nepal

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ABSTRACT

Food insecurity has been prevailing in the province for more than decades. Province lacks complete study on measures of food insecurity. So, an experiment and discussion with self-observation were conducted throughout the years to determine status and measures of food insecurity in Karnali, Nepal. The research was conducted in Jumla, Mugu & Surkhet of Karnali province with Split-plot design including two or three (as per technical requirement) mini plots to compare intensified or non-intensified cropping/inputs, conservational farming vs. non-conservational farming (three mini plots), artificial pollination vs natural pollination, and crop field protected with insect net vs. without net (part of plant protection), as part of experiment and field trials. Observation and self-study from various projects were carried out to determine status or opportunities of modern farming, drought resilient agriculture, value addition, and promotion of cereals/pseudo-cereals. KII (Key Informant Interview) and FGD (Focus-Group Discussion) conducted with farmer groups (Number:25) and government officials to determine the situation of food security and programs or policy influencing opportunities in the province. Application of innovative tools, technologies and skills through crop or rice intensification, conservational farming, breeding or genetic make-up, crop protection from insect/pest, opportunities of value addition centers, modern farming, and drought resilient agriculture with promotion of cereals or pseudo-cereals and policy influencing or advocacy opportunities have found most effective and sustainable methods of crop improvement for the potential measures of food insecurity in the province. Therefore, the study would support researchers to understand the contextual implications of food security in the province.

Contribution/Originality: The study combines different tools together to understand the efficiency of various food insecurity measures. This research varies with others in terms of contextual measures of options it has deployed to determine status and measures of food insecurity representing the whole province.

1. INTRODUCTION

Food security is the measure of an individual's ability to access food that is nutritious and sufficient in quantity. The United Nations World Food Program (WFP) reported that 110 out of 210 countries—primarily poor countries with subsistence agriculture—are facing food security problems and this number is expected to grow [1]. Nepal is one of the most food insecure countries in the world and ranks 157 among 187 countries [2, 3]. In 2010/2011, of Nepal's 75 districts, 38 are characterized as food insecure districts [4]. Jumla, Mugu and Humla are the major food deficit districts in Karnali Province. The condition of people in terms of food security is deteriorating in the province. People are vulnerable to food crises with the progressive time.

Many studies have been conducted to withstand food insecurity in Nepal. Among the various components of soil fertility legumes, if suitably inoculated, can fix 100 kg nitrogen per hectare to the soil. Intercropping, relay cropping or boundary cropping with legume-cereal could harbor soil fertility increasing crop production. Soybean increases yield of the following maize and most of the increase is due to their nitrogen contribution [5]. N-cycle management is utmost important for increasing sustainable yield and ecosystem. Soil organic matter (SOM) serves as the source of nutrients for crop plants [6]. Many adaptation strategies have been put forward in response to numerous adverse effects in Nepal [7]. At the local level, farming households have adopted strategies such as soil and water management, adjustments to the timing of farm operations and crop and varietal adjustment [8-11]. Fallow or misuse of land, low production, effects of climate change or crop insect or disease infestation and poor policy framework has resulted in an increase in food insecurity in Karnali Province. In this study, different methods and management strategies were screened and assessed to determine potential measures of food insecurity in the Karnali province of Nepal.

Objective: To determine most effective and sustainable measures of food insecurity.

2. MATERIALS AND METHODS

Field experiments and discussion were the major methods of research carried to assess the potential measures of food insecurity. Research conducted to improve soil, production or productivity, traits, quality, and policy of the province. The research was conducted in Jumla, Mugu & Surkhet of Karnali province from February 2020 to September 2024.

2.1. Research Design

Research carried to reflect both qualitative and quantitative aspects of the experimental field and community or stakeholder discussion.

2.2. Data and Information Collection Methods

2.2.1. Experimental Field

2.2.1.1. Methods and System Intensification

This includes demonstration or study of method or system intensification for tools and crops in a single entity. Such as, drought resilient farming, value addition, modern farming system, and promotion of cereals or pseudo-cereals.

2.2.1.2. Crop Trials and Comparison

Exclusively this method showcases the cropping comparison within the trial or research field. This includes crop intensification, legume farming or conservation agriculture, plant breeding & plant protection practices.

2.2.2. Discussions

Both primary and secondary sources were explored to generate data and information in influencing and policy frameworks of food security. Primary data include FGD with producers, & KII with government stakeholders (e.g., ministries, officials, etc.) while secondary through literature, books, guidelines, and previous findings.

2.3. Research and Analysis Process

2.3.1. Assessments of Experimental Fields

The field was divided into split plot design where each attribute or treatments were compared in two mini-plots. Process started with (land preparation) clearing, plowing, manuring, sowing, weeding, irrigation and to the harvesting. Each two mini plots designed to compare intensified or non-intensified cropping/inputs, conservational farming vs. non-conservational farming (three mini plots), plant breeding (artificial pollination) vs. non- breeding (natural pollination) crops and crop field protected with insect net vs. without net (part of plant protection).

System of rice intensification was determined by tagging middle lines of rice to study plant height, water requirements, etc. Similarly, samples of soil, maize-cowpea or maize standalone selected and studied with N-content in grains, weed infestation, etc. at the central area of mini-plots. The pollinating attributes carried with selected sample size, tagging, and bagging them, and self-deployed with cautious laboratory equipment. And one mini-plot of cabbage treated with pesticides (as control) and other netted through mosquito net as a part of plant protection protecting from aphids, leaf miner, etc. to assess seedling development, time for true leaf formation and cost of seedling management. Whole mini plot was studied, and sample seedlings were taken for final study.

To determine the efficacy of method & system intensification observation and study of value addition, drought resilient farming, modern farming, promotional activities of cereals and pseudo-cereals were carried out. The information and data collected from the various studies of the project, government body and individual assessment.

2.3.2. Primary and Secondary Data

The questionnaire was prepared to collect information and data form producers, government officials and ministries. FGD for 25 farmers to understand existing programs and plans of agriculture and food security in Karnali. KII with government or/and ministries conducted to determine actual plan, program, or framework of food security. In addition, they were asked about future possibilities, and scope of influencing on food security from producers or stakeholders.

2.4. Statistical Analysis

The primary and secondary data collected from the field was first coded and entered in the SPSS data sheet and analysis was done by using computer software packages; Statistical Package for Social Science (SPSS) version 21. Means & frequency distribution analysis were also performed.

3. RESULTS AND DISCUSSIONS

3.1. Crop Intensification of Rice

Through the system of Rice Intensification (SRI) method it was found that plant height after 45 days of transplanting became 20 cm compared with 36 cm from normal rice transplanting. After 60 days of transplanting the height of SRI rice revealed 30 cm while that of normal 45 cm. It was observed that water requirement for SRI rice was only 500 liters for one kg rice production while 1400 liter for one kg rice production in normal transplanting. And the yield through SRI found 350 kg/ropani compared to 200 kg/ropani through normal transplantation (Table 1).

SRI has been appreciated as one of the ways of agronomic manipulation for increased yield [12]. The number of research activities grew then after and the results showing the supremacy of SRI over conventional system of rice cultivation regarding the pant physiology, yield, water saving, and economic benefit started to appear [13, 14] of crop and rice intensification have increasing throughout the province. SRI has been considered as one of the food securing factors through providing cereal source through an economic and time effective way.

Table 1. Physiological attributes of system of rice intensification (SRI).

Methods of rice transplantation	Plant height @ 45 DAT (cm)	Plant height @ 60 DAT (cm)	Water requirement (lit/kg rice production)	Yield (kg/ropani)
System of rice intensification (SRI)	20	30	500	350
Normal transplanting of rice	36	45	1400	200

3.2. Conservation vs. Non-Conservation Farming

The study was based on three mini-plots with maize and cowpea intercropped in one mini-plot, sole cowpea only in another and maize in the third. It was observed from laboratory study that Nitrogen content in the intercropping & sole cowpea was 100% compared with only 10% in maize cropping. Quantity of soil microorganisms (i.e., Bacteria) assessed to be 300 X 10^4g^{-1} in intercropping followed by 335X 10^4g^{-1} in sole cowpea and 20 X 10^4g^{-1} in maize mini-plot respectively through the laboratory study. Average reduction of weed infestation in intercropped fields found 50 to 60% followed by 40% & 30% in cowpea and maize sole cropping. Similarly, average top-soil loss found 50% in intercropped mini-plot followed by 30% and 20% in cowpea and maize sole cropping respectively. The yield of intercropping mini plots for maize found 170 kg/ropani in comparison with 30 kg/ropani and 100 kg/ropani in the sole crop field of cowpea and maize respectively (Table 2). Legumes can provide up to 73% of the nitrogen required by cereals, depending on stand age, background soil available nitrogen, cropping system, and crop species [15, 16]. There are some socio economic, biological, and ecological advantages [17, 18] in intercropping over monocropping. Furthermore, intercropping cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen [19]. Except Maize+cowpea, maize+soyabean, maize+pigeonpea, etc. are some other examples of mixed or intercropping. Moreover, intercropping systems are efficiently used for the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce pests, diseases incidence and suppress weeds and favor soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility [20-24]. Improving soil fertility is the result of preserving top and valuable soil structure. It has been considered and found that cropping standing plants or maize or any legume have lower efficiency than cropping them together as mixed or intercropping. Ultimately increases yield or production in intercropped fields compared with monoculture.

Table 2. Intercropping and non-intercropping of cowpea and maize.

Cropping methods of cowpea	N-content in grain (%)	Soil micro-organisms (bacteria per ha)	Weed infestation (reduced average %)	Top-soil loss (av. in %)	Yield (kg/ropani)
Maize+ Cowpea (in maize)	100	300 X 10^4g^{-1}	50-60	50%	170
Cowpea	100	335X 10^4g^{-1}	40	30	30
Maize	10	20 X 10^4g^{-1}	30	20	100

3.3. Plant Breeding (Artificial Pollination) Vs. Non- Breeding (Natural Pollination)

The bagged open or natural pollinated & artificial pollination were compared in maize mini plot where weight of single ear in average found to be 32 g in artificial pollination while 155 g in natural pollination. Similarly, the number of kernels per ear on average found to be 260 in open or natural pollination compared with 20 only in artificial pollination. Total kernel weight per ear on average found to be 112 g in natural pollination followed by 7 g in artificial pollination (Table 3).

Comparative studies were conducted to evaluate the effects of open and hand pollination on several kernel quality traits, such as protein, oil, and carbohydrate content in maize kernels [25, 26]. It was found that the number of kernels, kernel weight, etc. were higher in open pollination compared with hand pollination, though sometimes the quality may be better in hand pollination.

Table 3. Artificial pollination vs. natural pollination in maize.

Methods of pollination	Single ear weight in av. (g)	Kernel number per ear (av.)	Total kernel weight per ear in av. (g)
Artificial pollination in maize	32	20	7
Natural (Open) pollination in maize	155	260	112

3.4. Protected Crop Field Vs. Non-Protected Crop Field

It was assessed that it took 3 Days after Sowing (DAS) for seedling emergence in protected cabbage cropping by net compared with 6 days after sowing to emerge seedling in controlled mini plot. Number of weeks for true leaf formation after seedling emergence happened to 1 in case of protected cabbage while 3 in the control field. The cost of seedling and land management is almost half for a protected cabbage mini plot compared with control one (Figure 1). This study was supported by numerous past studies that the seedling growth, number of leaves development and overall yield are highly influenced by protected cropping compared with normal through protecting insects, pests, and another external environment. The quality, yield, or volume of production of crops increases with protection or conservation from insect pests compared with non-protected crop lands [27].

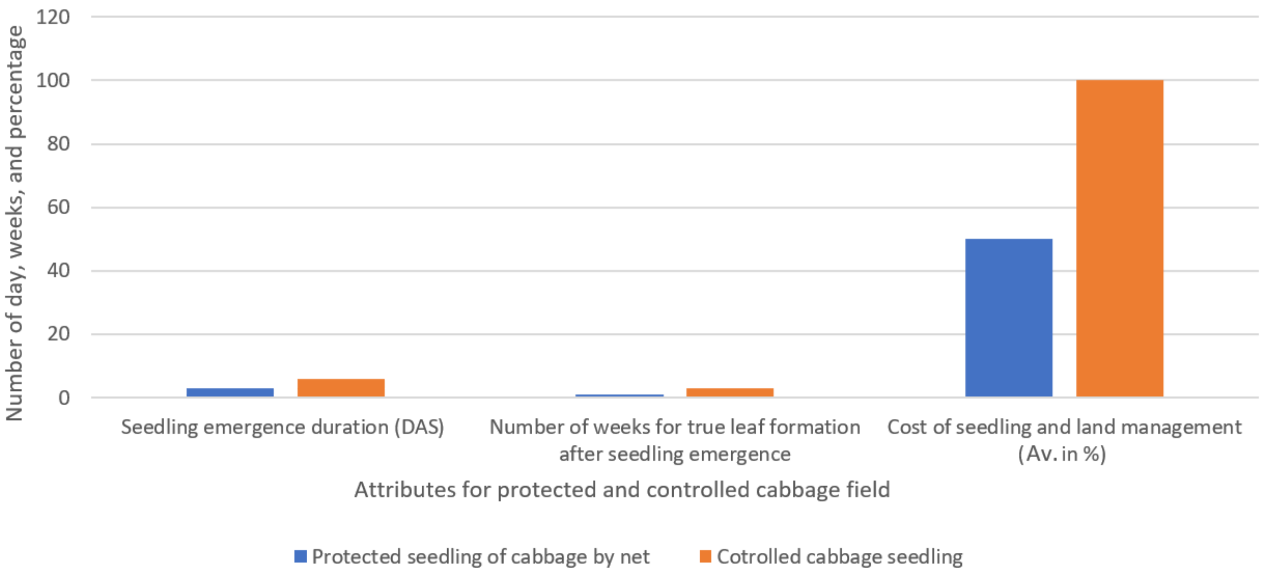

Figure 1. Comparison between protected and control cabbage field.

3.5. Value Addition

It was found that the numbers of processing units for value addition in 2020 was 3, 2 and 4 for turmeric, ginger, and potato (including other vegetables). It increased up to 9, 8, 15 for turmeric, ginger, and potato during 2024 (Table 4). Producers link closely to traders to increase value of their products, and the traders determine themselves as a part of the value adding component [28]. Such study agreed with past studies that private sectors and companies for value addition are always ready to accept the products such as ginger, turmeric, etc. for value addition and overall market system development. Producers are interested in adding value to the crops and improving their income resources by selling or supplying high quality commodities to the processing centers.

Table 4. Trend of increasing processing units.

Date wise transformation in processing units	Turmeric	Zinger	Potato
Number of processing unit in 2020	3	2	4
Number of processing unit in 2021	5	4	7
Number of processing unit in 2022	7	5	10
Number of processing unit in 2023	8	6	12
Number of processing unit in 2024	9	8	15

3.6. Drought Resilient Farming

The study carried out in Mugu, Karnali showed that the average percentage of people applying drought resilient seed of rice and maize was 28 and 30 respectively during 2021 followed by 20 and 22 during 2022, 14 and 17 during 2023, and 12 and 10 during 2024 (Figure 2). The study is in line with past research that climate resilient seeds and technologies have been declining in rural parts of the country may be because of lack of awareness or migration of people from hills to terai. However, droughts can create opportunities to explore different adaptation strategies that are suitable in such changing circumstances [29]. The variation in environment causing drought and other climatic crises have resulted in low production and ultimately food insecurity, and to mitigate such challenges improving climate or drought resilient varieties are crucial in hill parts of province.

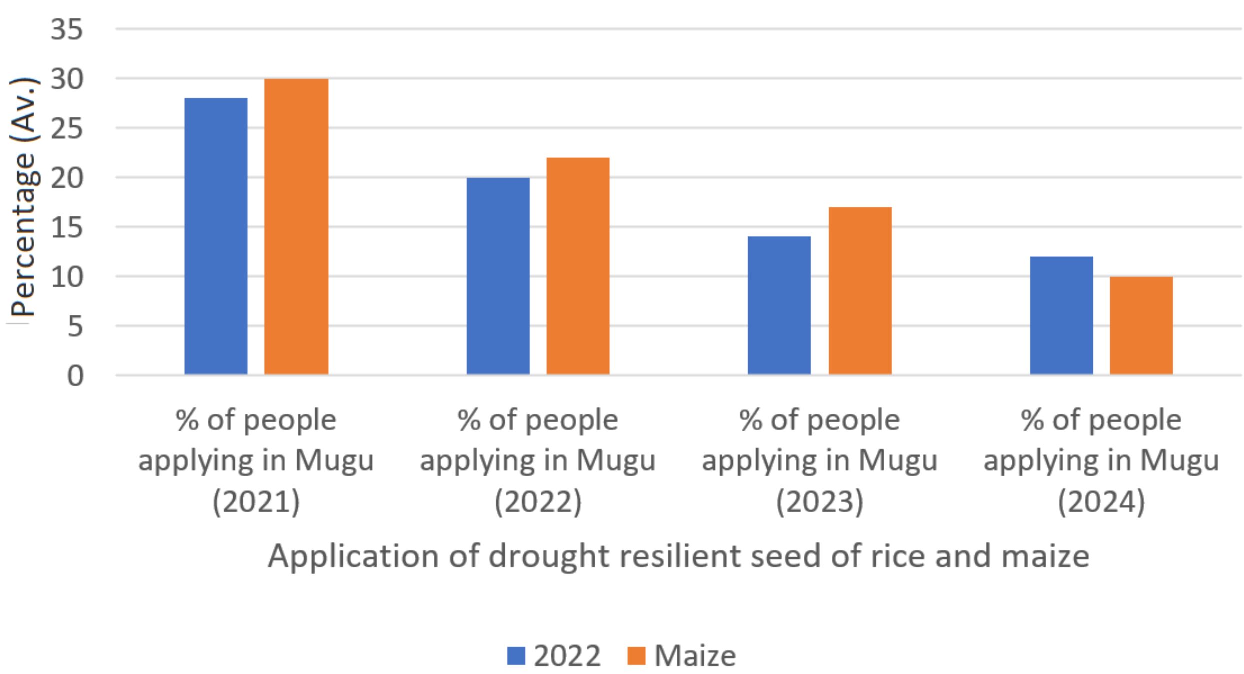

Figure 2. Trend of resilient seed application over time.

3.7. Modern Farming

The study carried in Jumla, Karnali revealed that the average percentage of farmers using tillage tractors in sub-urban site were 30, 40, 45 & 60 during 2021, 2022, 2023 and 2024 compared with 10, 13, 17, and 20 in rural sites during similar years. Similarly, the average percentage of sub-urban farmers using harvesting carats were found to be 40, 60, 70 and 80 during 2021, 2022, 2023 and 2024 as compared with 30, 35, 43, and 45 in rural areas during similar time (Figure 3). Various past studies revealed that the sub-urban or urban people are more aware about tools, technologies, and innovation in agriculture in comparison with rural people or farmers. Also, the rate of adoption of technologies and modern farming methods have been growing highly in sub-urban parts compared with rural parts in the province. This may be due to the level of affordability and accessibility as well. The adoption of modern technologies and methods are slowly improving in rural parts, while it is quickly increasing in urban or semi-urban country sites [30]. The past studies agree with finding of this research.

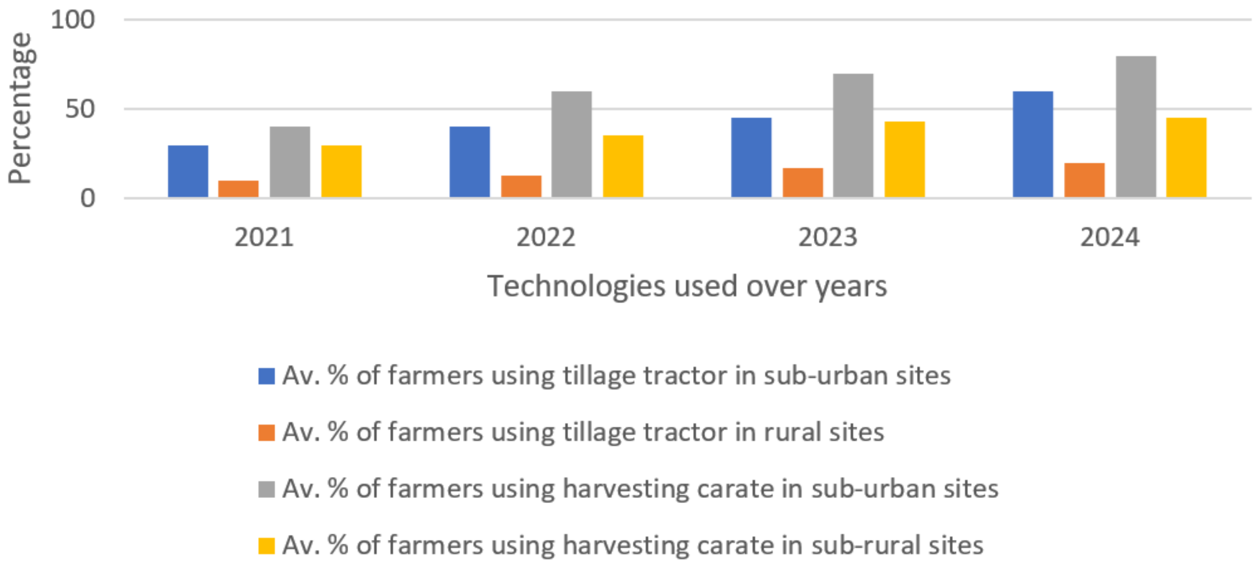

Figure 3. Trend of modern farming system over time.

3.8. Promotion of Cereals and Pseudo-Cereals

From the observation it was found that the preference and cropping of cereal and pseudo-cereal crops in hilly areas of Karnali has been declining. Almost half of the farmers in the study site have left to grow and cultivate crops such as maize, finger millet, etc. These crops are very important parts to maintain food security in the country even in the adverse circumstances of climate change [31-33] Loss of such crops could be regenerated through improvement and their promotion. There is a high possibility to rehabilitate and recover the loss and decline in cereal and pseudo-cereal crops which are regarded as important sources of food crops and contribute highly to food security.

3.9. Scope of Influencing in Food Security

After discussion with the local government, line ministries and officials it was found that the province has highly prioritized food security plans and programs in their calendar. After need assessment and discussion with farmers the future programs were aligned to improve crop production and marketing system. It was found that the local people, and stakeholder's have a high chance of influencing the ministries and government body to enhance food security in the province. All the policies and guidelines were not found in line with farmers' needs, food security purpose and crop improvement. Political constraints play a vital role in the improvement of food insecurity and related programs [34]. Studies and assessment have found that appropriate policy influencing was necessary for sustainable food security. Coordination, regular advocacy, and integration with government bodies (inter and intra) with producer groups and stakeholders was necessary to improve influencing in food security throughout the province. Therefore, many studies from past research agree with the above findings and details. The study and assessment clearly show that modern tools, technologies & skills for farming including policy influencing & scientific breeding or research to withstand impacts of changing circumstances are effective & sustainable methods to improve crop production and supply ultimately mitigating food insecurity in the province.

4. CONCLUSION

It was difficult to accumulate large amounts of information and data over an extensive study site at once. Food insecurity has been prevailing in the province for more than decades. Farmers and local people have been becoming poorer and inaccessible with food resources in the major rural parts of the province. An experiment and discussion with self-observation were conducted throughout the years to determine status and measures of food insecurity in Karnali, Nepal. Split-plot design with two or three (as per technical requirement) mini plots were prepared to compare intensified or non-intensified cropping/inputs, conservational farming vs. non-conservational farming (three mini plots), plant breeding (artificial pollination) vs. non- breeding (natural pollination) crops and crop field protected with insect net vs. without net (part of plant protection), as part of experiment and field trials. Observation and self-study from various projects were carried out to determine status or opportunities of modern farming, drought resilient agriculture, value addition, and promotion of cereals/pseudo-cereals. Thorough discussion with farmer groups and stakeholders was conducted to identify policy influencing status and as a key measure or food insecurity. All the attributes of research found positive and result oriented. Application of innovative tools, technologies and skills through crop or rice intensification, conservational farming, breeding or genetic make-up, crop protection from insect/pest, opportunities of value addition centers, modern farming, and drought resilient agriculture with promotion of cereals or pseudo-cereals and policy influencing or advocacy works have found most effective and sustainable methods of crop improvement for the potential measures of food insecurity in the province.

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Authors' Contributions: Conceptualization, Data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing original draft, review & editing, J.P.; data curation, formal analysis, investigation, methodology, project administration, visualization, writing original draft, review & editing, P.D. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] FAO, WFP, and IFAD, *The state of food insecurity in the world the multiple dimensions of food security*. Rome: FAO, 2013.

[2] UNDP, *Human development report. Sustainability and equity. A better future for all*. Washington, D.C: UNDP, 2011.

[3] K. D. Joshi, C. Conroy, and J. R. Witcombe, *Agriculture, seed, and innovation in Nepal: Industry and policy issues for the future*. Washington, D.C: Paper, Dec. 2012, IFPRI, 2012.

[4] Government of Nepal, *Agriculture atlas of Nepal*. Nepal: National Planning Commission Secretariat, 2012.

[5] J. O. Baldock, R. L. Higgs, W. H. Paulson, J. A. Jackobs, and W. D. Shrader, "Legume and mineral n effects on crop yields in several crop sequences in the upper mississippi valley 1," *Agronomy Journal*, vol. 73, no. 5, pp. 885-890, 1981. https://doi.org/10.2134/agronj1981.00021962007300050031x

[6] W. McGill and C. Cole, "Comparative aspects of cycling of organic C, N, S and P through soil organic matter," *Geoderma*, vol. 26, no. 4, pp. 267-286, 1981. https://doi.org/10.1016/0016-7061(81)90024-0

[7] B. Regmi, A. Paudyal, and P. Bordoni, *Climate change and agrobiodiversity in Nepal: Opportunities to include agrobiodiversity maintenance to support Nepal's national adaptation programme of action (NAPA)*. Pokhara: LI-BIRD, 2009.

[8] B. Dahal *et al.*, "Changing trends in cultivation practices and adoption of climate adaptive farming in Eastern Nepal," *Sustainable Agriculture Research*, vol. 7, no. 3, pp. 52-62, 2018. https://doi.org/10.5539/sar.v7n3p52

[9] M. Giri, M. Tiepolo, and S. Hada, "Household level adaptation practices to climate change in rural areas of Nepal. In: S. Pradhananga, J. Panthi, & D. Bhattarai, Eds," presented at the International Conference on Climate Change Innovation and Resilience for Sustainable Livelihood, Kathmandu, Nepal, 2015.

[10] U. Khanal, C. Wilson, V.-N. Hoang, and B. Lee, "Impact of community-based organizations on climate change adaptation in agriculture: Empirical evidence from Nepal," *Environment, Development and Sustainability*, vol. 21, pp. 621-635, 2019. https://doi.org/10.1007/s10668-017-0050-6

[11] S. Maharjan, K. Maharjan, U. Tiwari, and N. Sen, "Participatory vulnerability assessment of climate vulnerabilities and impacts in Madi Valley of Chitwan district, Nepal," *Cogent Food & Agriculture*, vol. 3, no. 1, p. 1310078, 2017. https://doi.org/10.1080/23311932.2017.1310078

[12] B. Basnet, "Rice technologies and their sensitization for poverty reduction," in *Proceedings of the 7th National Outreach Research Workshop, Outreach Research Division, NARC*, 2005, pp. 15-18.

[13] M. Bhatta and J. Tripathi, "On-station and on-farm studies on system of rice intensification (SRI)," presented at the SRI Workshop, ICIMOD, Lalitpur, Nepal, 2005.

[14] M. Dhakal, "Farmers' evaluation of the system of rice intensification in the middle mountains of Nepal." Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD), 2005, p. 33.

[15] M. S. Thilakarathna, M. S. McElroy, T. Chapagain, Y. A. Papadopoulos, and M. N. Raizada, "Belowground nitrogen transfer from legumes to non-legumes under managed herbaceous cropping systems. A review," *Agronomy for Sustainable Development*, vol. 36, pp. 1-16, 2016. https://doi.org/10.1007/s13593-016-0396-4

[16] E. C. Reilly, J. L. Gutknecht, N. E. Tautges, C. C. Sheaffer, and J. M. Jungers, "Nitrogen transfer and yield effects of legumes intercropped with the perennial grain crop intermediate wheatgrass," *Field Crops Research*, vol. 286, p. 108627, 2022. https://doi.org/10.1016/j.fcr.2022.108627

[17] P. Aggarwal, D. Garrity, S. Liboon, and R. Morris, "Resource use and plant interactions in a rice-mungbean intercrop," *Agronomy Journal*, vol. 84, no. 1, pp. 71-78, 1992. https://doi.org/10.2134/agronj1992.00021962008400010015x

[18] C. Fininsa, "Effect of intercropping bean with maize on bean common bacterial blight and rust diseases," *International Journal of Pest Management*, vol. 42, no. 1, pp. 51-54, 1996. https://doi.org/10.1080/09670879609371969

[19] W. Beets, "Multiple cropping and tropical farming systems." Boulder: Westview Press, 1982, p. 156.

[20] F. Ofori and W. Stern, "Cereal–legume intercropping systems," *Advances in Agronomy*, vol. 41, pp. 41-90, 1987. https://doi.org/10.1016/s0065-2113(08)60802-0

[21] N. Sanginga and P. Woomer, *Integrated soil fertility management in Africa: Principles, practices, and development process*. Nairobi: Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, 2009.

[22] P. Jeranyama, O. B. Hesterman, S. R. Waddington, and R. R. Harwood, "Relay-intercropping of sunnhemp and cowpea into a smallholder maize system in Zimbabwe," *Agronomy Journal*, vol. 92, no. 2, pp. 239-244, 2000. https://doi.org/10.1007/s100870050028

[23] B. Horwith, "A role for intercropping in modern agriculture," *BioScience*, vol. 35, no. 5, pp. 286-291, 1985. https://doi.org/10.2307/1309927

[24] R. Willey *et al.*, "Ciba Foundation Symposium 97-Better Crops for Food. Chichester, UK: John Wiley & Sons, Ltd," 1983, pp. 83-100.

[25] M. Letchworth and R. Lambert, "Pollen parent effects on oil, protein, and starch concentration in maize kernels," *Crop Science*, vol. 38, no. 2, pp. 363-367, 1998. https://doi.org/10.2135/cropsci1998.0011183x003800020015x

[26] F. Kahrıman, C. Ö. Egesel, T. Aydın, and S. Subaşı, "The role of artificial pollination and pollen effect on ear development and kernel structure of different maize genotypes," *Journal of Pollination Ecology*, vol. 15, pp. 6-14, 2015. https://doi.org/10.26786/1920-7603(2015)1

[27] J. Van Den Berg, "Socio-economic factors affecting adoption of improved agricultural practices by small scale farmers in South Africa," *African Journal of Agricultural Research*, vol. 8, no. 35, pp. 4490-4500, 2013. https://doi.org/10.5897/ajar12.1025

[28] D. Choudhary, M. S. Kunwar, and G. Rasul, "From Farmers to Entrepreneurs—Strengthening Malta orange value chains through institutional development in Uttarakhand, India," *Mountain Research and Development*, vol. 35, no. 1, pp. 4-15, 2015. https://doi.org/10.1659/mrd-journal-d-14-00036.1

[29] H. B. Dulal, G. Brodnig, H. K. Thakur, and C. Green-Onoriose, "Do the poor have what they need to adapt to climate change? A case study of Nepal," *Local Environment*, vol. 15, no. 7, pp. 621-635, 2010. https://doi.org/10.1080/13549839.2010.498814

[30] K. G. Liakos, P. Busato, D. Moshou, S. Pearson, and D. Bochtis, "Machine learning in agriculture: A review," *Sensors*, vol. 18, no. 8, p. 2674-2702, 2018.

[31] S. Das, R. Khound, M. Santra, and D. K. Santra, "Beyond bird feed: Proso millet for human health and environment," *Agriculture*, vol. 9, no. 3, p. 64, 2019. https://doi.org/10.3390/agriculture9030064

[32] T. L. Goron and M. N. Raizada, "Genetic diversity and genomic resources available for the small millet crops to accelerate a New Green Revolution," *Frontiers in Plant Science*, vol. 6, p. 157, 2015. https://doi.org/10.3389/fpls.2015.00157

[33] C. Habiyaremye *et al.*, "Proso millet (Panicum miliaceum L.) and its potential for cultivation in the Pacific Northwest, US: A review," *Frontiers in Plant Science*, vol. 7, p. 1961, 2017. https://doi.org/10.3389/fpls.2016.01961

[34] B. Chapagain and P. Gentle, "Withdrawing from agrarian livelihoods: Environmental migration in Nepal," *Journal of Mountain Science*, vol. 12, no. 1, pp. 1-13, 2015.