

ADOPTION OF CLIMATE RESILIENT AGRO-ECOLOGICAL PRACTICES IN THE KARNALI RIVER BASINS

Sagar GC^{1*}, Ram Bahadur Rana², Parshuram Bishwokarma² and Buddha Bahadur BK¹

¹Local Initiative for Biodiversity Research and Development (LI-BIRD), Pokhara, Nepal

²LI-BIRD Consulting Pvt. Ltd., Pokhara, Nepal

*Corresponding author email: gcsagar92@gmail.com

Sagar GC: <https://orcid.org/0000-0003-3197-8776>

Ram Bahadur Rana: <https://orcid.org/0000-0003-3974-0738>

Parshuram Bishwokarma: <https://orcid.org/0009-0006-4899-4130>

ABSTRACT

Karnali province, with an HDI of 0.53, cannot compete with other provinces on production and productivity due to mountainous terrains. It is rich in agrobiodiversity and indigenous knowledge systems shaped by diverse climate, culture and food systems which allow to practice agro-ecology based production systems. The promotion of local, safe and healthy food systems through the adoption of ecological practices is the only option to get better return from agricultural production and improve the food and nutrition insecurity of the province. The study aims to identify the climate resilient agro-ecological practices practiced by the people and how the socio-economic condition of the people affects the adoption of such technologies and practices. Data collected through household surveys, Focus Group Discussion (FGD) and Key Informant Interviews (KII) from the Karnali river basin districts were analyzed using descriptive and inferential statistics. Results showed that eighteen different climate resilient agro-ecological practices categorized under six different headings such as cropping/planting method, resilient seed/breed, disease and pest management, water management, carbon/nutrient management and farmer's risk reduction were found being practiced by the farmers. The highest number of climate resilient ecological practices were found being practiced in pulses (11), followed by cereals, vegetables, and oil crops (10). Women were more trained in agro-ecological farming than men. Each variable of the socio-economic condition except caste and income showed a significant relationship with the adoption of climate resilient agro-ecological practices. Awareness along with participatory engagement of the various stakeholders in demonstrating the practices and generating evidence can be suggested to convince them to the promotion of agro-ecology.

Keywords: agro-ecology, socio-economic condition, climate resilient, awareness

INTRODUCTION

Agro-ecology is a bridge to promote a dialogue between modern scientific agriculture and the agriculture based on indigenous/local knowledge with a concept of developing a resilient agro-ecosystem having minimal dependence on the external inputs and have a synergy and interactions among different biological components of the system (Vijikumar, 2010). It is a way forward for such agriculture that delivers the productivity goal without depleting the environment and disempowering the farming community (Altieri, 2015). Agro-ecology can meet the economic, social and environmental needs of the farming community maintaining environmental and social resilience. It is a scientific discipline, a sustainable farming approach and a social movement in the context of the current changing climate and growing concerns over the healthier food system. More evidence, like case studies, are being generated stating its multiple benefits from climate resilience to farm productivity (Silici, 2014). It has 10 functional elements: diversity, synergies, efficiency, resilience, recycling, co-creation and sharing of knowledge, human and social values, culture and food traditions, responsible governance, and circular and solidarity economy (FAO, 2018). Since agro-ecology is based upon the bottom-up and territorial processes that help to deliver context-based solutions to local problems enhancing their adaptive capacity and empowering producer communities as a key agent of change, it is unique to other approaches of agriculture (Bisht et al., 2022).

Karnali province with HDI of 0.53 (UN Nepal, 2021) is one of the least developed provinces in the country. The province is not able to compete with the other provinces in terms of production and productivity due to its geography and having less capital for the investment; consequently, it is a food deficit province. One of the options the province has is to promote locally available agricultural products, add value to them and promote their production at scale. One of the best ways of achieving that objective would be the promotion of agro-ecology. Since the province is also preparing the province to declare an organic province, agro-ecology is the best to practice as an alternative that is affordable for the province. Large scale adoption of different agro-ecological practices and technologies being popular among the farmers can become better alternatives to the agro-chemicals. Therefore, it is necessary to find out those alternatives, understand their efficacy, cost-effectiveness, and ease of application, etc. so that farmers can apply them.

This paper aims to identify the socio-economic conditions of the farming communities, document existing agro-ecological practices and technologies adopted by the farming communities categorizing them under six different headings: i) Cropping/planting method ii) Resilient seed/breed iii) Disease and pest management iv) Water management v) Carbon/nutrient management, and vi) Farmers risk reduction, their

contribution in ecological resilience and explore the relationship between the socio-economic conditions of the farming communities and adoption of these agro-ecological technologies and practices in the province.

METHODOLOGY

Districts situated in the Karnali river basin (Surkhet, Dailekh and Accham) were selected for the study. A structured questionnaire to understand the socio-economic conditions and present status of ecological practices in the region was developed taking reference from the national and international reports and journal articles. Six enumerators were selected for the data collection, two enumerators per district. The data collection process was carried out in Birendranagar Municipality and Barahatal Rural Municipality of Surkhet district, Dullu Municipality and Aathbis Municipality of Dailekh district, and Turmakhad Rural Municipality and Panchadewal Rural Municipality of Accham district. The tools used for the study were household surveys, focus group discussions (FGD) and key informant interviews (KII). Enumerators were oriented for two days on questionnaires and data collection using tablets. Pre-testing of the questionnaire was done to generate confidence in the enumerators and to check the quality of the questionnaire developed. All the beneficiaries (2500) of the Green Karnali project were considered as a sample. The sample size was calculated with a 5 percent margin of error a 95 percent level of significance (1- α) considering one-tailed with a 10 percent non-response rate (NR). Thus, the obtained sample size (268) was further distributed proportionately to each municipality and rural municipality, and the final sample size required was calculated with some adjustments. The adjustments were made by increasing the size of the sample by keeping in mind the number of beneficiaries from each district. In total, 310 households (persons) were surveyed (80 in Accham, 110 in Dailekh, and 120 in Surkhet) along with 13 FGDs and 11 KIIs. The two-stage stratified random sampling was adopted to select the respondents where municipalities were considered as strata. After that, in the first stage, groups were selected from each municipality, and 10 beneficiaries were selected randomly from each group for data collection. Inclusiveness of the marginalized groups and disadvantaged groups was the prime focus during the entire survey period. It included the poor, women, people with disability, Dalits, and ethnic minorities. Real-time and actual GPS location of data collection was tracked by collecting the data through tablets to ensure the data quality. The filled questionnaire was checked regularly to ensure accurate information and instant technical backstopping to enumerators when needed. The data collected was cleaned and analyzed using Excel and SPSS. Descriptive statistics including frequency, percentage and mean were used. Logistic Regression was used to establish the relationships between different socio-economic variables (caste, income, family size, land ownership, land size, gender, age, and education) and the adoption of different agro-ecological farming practices in the farms. The result obtained from the

household survey was triangulated with the qualitative information gathered through different complementary sources including direct observations, KII, FGD and literature review. Under the climate resilient agro-ecological practices study, the practices common in the Karnali river basin were reviewed and categorized under six different headings: i) Cropping/planting method ii) Resilient seed/breed iii) Disease and pest management iv) Water Management v) Carbon/nutrient management, and vi) Farmers risk reduction.

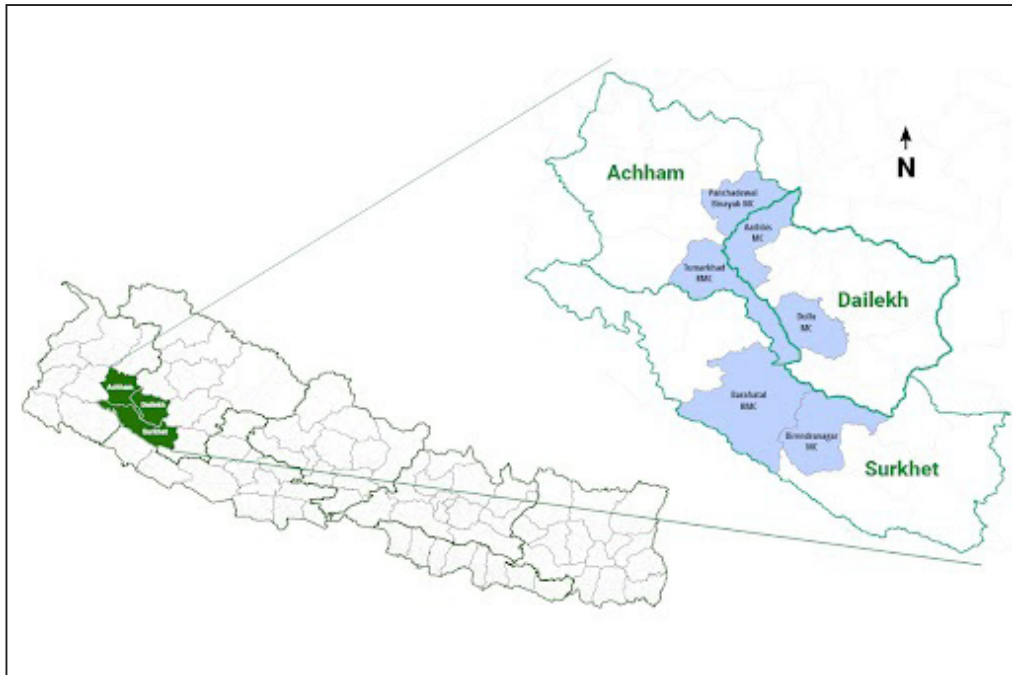


Figure 1. A map of Nepal with the study district and the local governments.

RESULTS AND DISCUSSION

Socio-economic status of the respondents

From the study, most of the respondents (44.8 percent) were from the age group 25-40, followed by the age group 41-60 (36.5 percent). Among the respondents, 31.3 percent were found to have basic level (1-8) education followed by secondary level (9-12) education (28.1 percent) and 24.5 percent of the respondents were illiterate. Major ethnicity of the region was found to be Brahmin/Chhetri (66.8 percent), Janajati (20 percent) and Dalit (13.2 percent). The family size of 4-6 people per household was found to be the highest (60.3 percent).

34 percent of the people in Karnali province are illiterate (Republica, 2022), which is slightly more than what we observed in the study (25.5 percent). According to Nepal Outlook (2022), the percentage of Brahmin/Chhetri is 60.6 percent, Magar is 10.3 percent, Dalits (19.8 percent) and others (9.3 percent) and 80 percent of the total

population is engaged in agriculture (KPPC, 2020). Almost 76.8 percent of the households were landless or land poor farmers having less than 0.50 ha of land. About 19.4 percent of the farmers fall under the category of ‘subsistence farming’ with land holdings of 0.5–1.0 ha and only 3.9 percent of the farmers fall under the category of small commercial farmer. The findings are supported by FNCCI, (2020), which states the average land holdings of the Karnali Province as 0.53 ha per holdings. 77.1 percent of the respondents were found cultivating crops in less than 0.5 ha of land comprising 41 percent having less than 0.25 ha and 35.5 percent having the land between 0.25 ha to 0.5 ha. Comparative analyses of these socio-economic parameters between the study sites and Karnali Province indicate that these figures are comparable to a large extent thereby suggesting that the findings from the study are representative of the Karnali province.

Climate resilient agro-ecological practices

Household adopting various climate resilient agro-ecological practices in cultivation.

Result showed that that some form of climate resilient agro-ecological practices was found to be used in all farming practices including livestock (cereal crops, vegetable crops, pulse crops, oils crops, spices crops and livestock rearing) (Table 1). Farmers practiced 11 different climate resilient ecological practices in pulses followed by 10 different climate resilient ecological practices in both cereal and vegetable crops. Only 5 different climate resilient ecological practices were found to be adopted in livestock rearing. Crop diversification, bio-fertilizers/biopesticides, Disease/pest-resistant crops, integrated pest management and irrigation management/water harvesting/uplifting are the climate resilient agro-ecological practices adopted in all the crops (cereal, vegetables, pulses, oils and spices). The most common climate resilient ecological practice practiced by the households is the use of farmyard manure/compost i.e., 27.4 percent in cereals, 30 percent in vegetables, 20 percent in pulses, 13.5 percent in oil crops. The promotion of small-scale irrigation and furrow bed planting is only practiced in vegetable crops (13.2 percent) and (21.0 percent), respectively. Rana et. al., (2022) also reported that most of the farmers of Karnali province are adopting different agro-ecological practices like mulching, improved seed, and crop rotation. Among the 18 different climate resilient agro-ecological practices, 11 of them were indigenous/traditional practices whereas 7 of them were externally introduced practices. Externally introduced practices may be due to the support from government and projects. These practices seem to be very important in disease/pest management and water management. Many of the technologies that are being used by the farmers are the traditional practices that are transferred from generation to generation. Some of the externally introduced technologies and practices used by the farmers are not intentionally adopted by the farmers after understanding the climate change impacts, but it is due to the support of these technologies and practices from the various organizations and government agencies (Karki et al., 2020).

Table 1. Household utilizing climate resilient agro-ecological practices in different types of crop cultivation.

| Practices | Cereal crops | | Vegetable crops | | Pulse crops | | Oil crops | | Spice crops | | Livestock rearing | |
|---|--|------|-----------------|-----|-------------|-----|-----------|--|-------------|--|-------------------|--|
| | | | | | | | | | | | | |
| Cropping/planting method | | | | | | | | | | | | |
| Indigenous/traditional practices | Externally introduced practices | | | | | | | | | | | |
| Crop Diversification | 21.3 | 25.2 | 17.1 | 7.1 | 20.0 | 0.0 | | | | | | |
| Cropping system (crop rotation) | 23.2 | 0.0 | 17.1 | 8.7 | 0.0 | 0.0 | | | | | | |
| Contour planting | 9.7 | 0.0 | 7.4 | 0.0 | 0.0 | 0.0 | | | | | | |
| Furrow bed planting | 0.0 | 21.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | | | |
| Resilient seed/breed | | | | | | | | | | | | |
| Indigenous/traditional practices | Externally introduced practices | | | | | | | | | | | |
| Promotion of local varieties | 2.3 | 0.0 | 1.3 | 0.6 | 2.6 | 0.0 | | | | | | |
| Local breed of animals | 0.0 | 24.2 | 0.3 | 0.0 | 0.0 | 0.0 | | | | | | |
| Disease and pest management | | | | | | | | | | | | |
| Indigenous/traditional practices | Externally introduced practices | | | | | | | | | | | |
| Integrated pest management | 3.9 | 12.6 | 2.3 | 1.9 | 3.5 | 0.0 | | | | | | |
| Water management | 4.5 | 0.0 | 4.2 | 2.6 | 3.9 | 0.0 | | | | | | |
| | 4.8 | 7.1 | 3.2 | 2.6 | 3.9 | 0.0 | | | | | | |

| | | | | | | |
|--|--|------|------|------|------|------|
| Indigenous/traditional practices | Externally introduced practices | | | | | |
| Irrigation management/water harvesting/uplifting | 16.1 | 11.3 | 11.3 | 5.8 | 12.6 | 2.6 |
| | 0.0 | 13.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 0.0 | 11.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| Carbon/Nutrient management | | | | | | |
| Indigenous/traditional practices | Externally introduced practices | | | | | |
| Farmyard manure/Compost | 27.4 | 30.0 | 20.0 | 13.5 | 28.7 | 0.0 |
| Mulching | 13.9 | 23.2 | 12.9 | 5.5 | 32.3 | 0.0 |
| Improved animal shed/hive/sty | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.3 |
| | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.3 |
| Farmer's risk reduction | | | | | | |
| Indigenous/traditional practices | Externally introduced practices | | | | | |
| | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.3 |
| Not practiced/not farming | 69.7 | 63.2 | 77.7 | 85.5 | 64.8 | 85.8 |

Note: Percentage adds up to more than 100 due to multiple responses.

Cropping/planting method

Crop diversification manages the problems related to crop productivity, depletion in soil quality, food security and climate change mitigation affecting soil carbon regulating the soil carbon balance. However, Martinez-Mena et.al. (2021) stated that crop diversification with the perennial crop species increases the annual soil carbon content but that with annual species cannot. According to Zhang et.al., (2020) crop diversification enhances the range of biological products that enhance the performance of crops, nitrogen fixing bacteria, arbuscular mycorrhizal fungi, Trichoderma, and other microorganisms that have great potential of increasing the sustainability in agriculture. Cropping system (crop rotation) improves the soil condition and increases productivity. It also contributes to the sustainable soil development by reducing the insect and disease incidence, suppressing weeds, and improving the physiochemical properties of the soil (Shah et.al., 2021; Yang et.al., 2020). Farming with contour furrows and raised beds promotes soil and water conservation, reforestation of slope, development of irrigation and agroforestry in cropland (Gebreegziabher et.al., 2009).

Resilient seed/breed

Resilient seeds/breeds promote agro-ecological resilience from the different aspects by fostering genetic diversity, crop species diversity and diversity at the landscape level. They reduce seed supply channels thereby reducing the use of external resource inputs (Klien & Sievers-Glotzbach, 2022). Resilient seeds also help in conservation of soil and water, efficient water management, in agriculture system local seed reduces the negative impact of climate change and assures the stability in crop production strengthening the capacity of the agro-ecosystem to combat against abiotic and biotic stresses (Climate ADAPT, 2021; Singh et.al., 2015).

Disease and pest management

Chemical fertilizers and pesticides are the major factors deteriorating the quality of soil health, water system and the whole of agroecology. Since agro-ecology is an approach with no harm to soil, water, forest, and mankind, it is important to promote biofertilizers and bio-pesticides that do not harm the ecosystem and maintain balance among inhabitants within the agro-ecosystem (G.C., 2015). Biofertilizers contains different beneficial microorganisms that help in nitrogen fixation, phosphorus solubilization, potassium solubilization and mixture of other beneficial fungi and molds that can play a critical role in advance crop nutrient management. They play a vital role in safeguarding the environment by being cost effective options and eco-friendly to the producers (Rehman et.al., 2022). Integrated Pest Management (IPM) is about considering all the techniques

and measures that reduce disease and pests while minimizing risk to human health and environment. It makes the effective use of local knowledge, experience, technology, and local resources that promotes pollination as well as sustainable agro-ecosystem in a socially acceptable way (Croplife International, 2014; Franco, 2020; FAO, 2022).

Water management

Effective and judicious management of water is the valuable constituent of environment, nature conservation and agricultural production. In areas with water scarcity, major thrust is to minimize the use of water and reduce its loss through evaporation or percolation beyond the depth of the root zone (Chartzoulakis & Bertaki, 2015). Water harvesting and multiple use of water in water stagnant or water-logged areas through the construction of a canal and re-collecting it again by making a fishpond and planting vegetables and fruits along the bunds is a popular practice among the farmers (Upadhyaya, 2015; Bhusal et. Al., 2020). Polyhouse/plastic tunnels are found to significantly increase the yield of the crop and protect the crops from climate change effects such as heavy rainfall and cold weather (Kc et.al., 2021).

Carbon/nutrient management

Improved livestock shed always gives quality FYM and adequate amount of urine for the farm. Use of farmyard manure significantly increases organic matter content in the soil along with soil pH, improves water holding capacity of the soil, reduces water runoff, benefits environment by recycling organic resources, add nutrients and microbes in soil and provides the supplemental amount of slow-release nutrients (Giesel & Seaver, 2009; Gautam et.al., 2018). Organic mulching protects from soil erosion, conserves the moisture and assists plants in maintaining even temperature in the soil and controls weed growth. Mulching helps in the addition of soil organic matter, humus and nutrients to the soil providing substrate for beneficial microorganisms (Ngosong et.al., 2019).

Farmer's risk reduction

Climate change has extreme impacts on landslides, flood, drought, and brings difficulties in agriculture causing a huge economic losses. Livestock insurance is a tool to mitigate the climate hazards in the livestock sector in Nepal (Koirala & Bhandari, 2018).

Households with a number of climate resilient agro-ecological practices adopted

The highest percentage of people not using any climate resilient agro-ecological practices was observed in livestock rearing and oil crops (85.8 percent and 85.5 percent) respectively followed by pulses (77.7 percent). In terms of the number of different climate

Interrelationship of various socio-economic variables with the adoption of climate resilient agro-ecological practice

Test results show that the adoption of climate resilient agro-ecological practices is significantly different with the socio-economic variables of the households except the caste and income level of the people. Adoption of the climate resilient agro-ecological practices like use of bio-pesticide, IPM technology, Improved FYM, Use of plastic house are significantly different among the surveyed district at 99% level of confidence ($p < 0.01$) whereas the practices like crop diversification, Water harvesting/Irrigation management, Indigenous crop cultivation are significant at 95% level of confidence ($p < 0.05$). Use of drip irrigation was significant in the surveyed district at 90% level of confidence ($P < 0.1$) but the mulching practice is common across the districts. This may be due to the promotion of bio pesticides, plastic house and livestock shed improvement by the different stakeholders working in the agriculture sector and their presence in the study area (Ghimire et.al., 2022).

Looking at other social characteristics, the crop diversification practices were significantly different with Family size ($p < 0.1$), Land ownership ($p < 0.05$) and Land size ($p < 0.01$). Households having higher family members and owning their own land have been found to have higher crop diversification. Land holding size is found to have a highly significant relation with crop diversification, and this may be due to the household with higher land size having higher number of crops in the field and vice versa. Similarly, cultivation of Indigenous crops was also significantly different with the family size ($p < 0.1$), Land ownership ($p < 0.01$) and Land size ($p < 0.01$) which may be due to small size families growing less in small areas. This may be due to the households having large area not being able to buy hybrid seeds for this bigger land size.

The use of plastic houses was significantly different at 1 % level of significance at 99% level of confidence interval with family size. It may be due to the quantity of vegetables required in the house and the number of people required to work in the tunnel during its establishment and producing crops. The use of Bio pesticide was significant with Gender ($p < 0.05$), this may be due to the higher engagement of women in spraying of the bio-pesticides and men in other works. The IPM technology was significantly different with level of education ($p < 0.05$), which is true because IPM is knowledge-intensive that require certain level of education for the use of IPM technologies such as identifications of labels of the bio-pesticides, knowledge of identifying agro-chemicals and bio-pesticides, methods of using traps etc. The water harvesting/irrigation management

was also significant with age level of the respondent ($P < 0.1$), which may be due to the engagement of certain age of people in water harvesting/Irrigation management works such as involvement of only youths in water harvesting, canal construction work etc. The other two socio-economic variables did not show any correlation with climate resilient ecological practices. In the case of caste, it might be due to the higher number of respondents being from the same caste (Brahmin/Chhetri (66.8 percent) and the reason behind the income not showing any relationship with the adoption of climate resilient technologies could be due to the collection of income only from the agriculture, which did not vary much amongst the households. According to Rana et al. (2022), the adoption of agroecological studies is governed by different socio-economic variables. Adoption of agroecology technologies and practices showed significant results with Age, gender, and income. Youth can learn faster and take risks in the adoption of the technologies and practices. Rao et al. (2021) also stated the influences of socio-economic variable in the adoption of climate resilient technologies and practices.

CONCLUSION

The study concludes that farmers should be aware of the technologies they are using are climate resilient agro-ecological technologies and their importance in the maintenance of the ecosystem balance. If not, once they have access to agro-chemicals and modern inputs, they can leave these practices and degrade their agro-ecosystem. Weaning farmers from the use of agro-chemicals would be an uphill task once they are hooked. In Karnali Province there is use of modern input and wide scale application of agro-chemicals is limited which creates the opportunity to orient and train farming communities on agro-ecology based farming that fully focuses on practical aspects with the optimum utilization of indigenous knowledge and local resources.

Socio-economic variables are found to impact the adoption of climate resilient ecological practices. To effectively promote agro-ecological technologies and practices and to provide alternatives to conventional farming systems, these variables are to be considered. Since the understanding level of the farmers differ among each other, promotion of these practices should be arranged in such a way that these practices are demonstrated engaging the farming communities and the evidence is shown in front of their eyes. Better targeting of technologies according to different socio-economic condition of households stand a better chance of adoption of these technologies.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of any interest.

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REFERENCES

- Adhikari, S. (2018). *An overview of Climate Smart Agriculture in ASHA project*. <http://asha.gov.np/wp-content/uploads/2018/12/An-overview-of-CSA-in-ASHA.pdf>
- Altieri, M. A. (2015). *Agroecology, key concepts, principles and practices*. Third World Network (TWN)-SOCLA. Jutaprint. Penang. Malaysia.
- Bisht, I. S., Rana, J. C., Jones, S., Estrada-Carmona, N., & Yadav, R. (2022). Agroecological approach to farming for sustainable development: the Indian scenario. *Biodiversity of Ecosystems*, 107.
- Bhusal, A., Khatri, L., GC, S., Mandal, I., Bhatt L.P., Pudasaini, N., Katuwal, Y., Mishra, S., Gautam, A., Shiwakoti, T. & Dhakal, B. (2020). *Compendium of Climate-Smart Agriculture Technologies and Practices*. Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and Ministry of Land Management, Agriculture and Co-operative (MoLMAC), Gandaki Province, Pokhara, Nepal. <https://cgspace.cgiar.org/items/e47e2c4d-6952-4666-a25b-020e87493259>
- Chartzoulakis, K. & Bertaki, M. (2015). *Sustainable water management in agriculture under climate change*. *Agriculture and Agricultural Science Procedia*, 4, pp.88-98.
- Climate ADAPT, 2021. Use of adapted crops and varieties. <https://climate-adapt.eea.europa.eu/metadata/adaptation-options/use-of-adapted-crops-and-varieties>.
- CropLife International, 2014. Integrated pest Management. https://croplife.org/wp-content/uploads/pdf_files/Integrated-pest-management.pdf
- FAO, 2018. *The 10 elements of agroecology: guiding the transition to sustainable food and agricultural systems*. Pest and Pesticide Management. <https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/>

- FNCCI. (2020). *Appraisal report on potential agriculture processing industries in Karnali Province*, FNCCI/AEC and MoLMAC. https://www.aec-ncci.org/Uploads/Final_Report_Karnali.pdf
- Franco, J. C. (2020). Integrated pest management: sustainable approach to crop protection. *Encyclopedia of the UN Sustainable Development Goals Life on Land*, 551-559.
- Gautam, D. K., Bajracharya, R. M. and Sitaula, B. K. (2017). Effects of biochar and farm yard manure on soil properties and crop growth in an agroforestry system in the Himalaya. *Sustainable Agriculture Research*, 6(4), 74-82.
- GC, Y. D. (2015). Bipesticides: effective alternative to organic Nepal. *Journal of Agriculture and Environment*, 16, 95-102.
- Gebreegiabher, T., Nyssen, J., Govaerts, B., Getnet, F., Behailu, M., Haile, M. and Deckers, J. (2009). Contour furrows for in situ soil and water conservation, Tigray, Northern Ethiopia. *Soil and Tillage Research*, 103(2), 257-264.
- Geisel, P. & Seaver, D. (2009). *Composting is good for your garden and the environment*. UCANR Publications.
- Ghimire, R., Khatri-Chhetri, A., & Chhetri, N. B. (2022). *Institutional innovations for climate smart agriculture: assessment of climate-smart village approach in Nepal*. *Frontiers in Sustainable Food Systems*, 205. Nepal Outlook, 2022. Karnali province: A data overview. [https://nepaloutlook.com/karnali-province/#:~:text=The%20largest%20ethnic%20group%20in,1.7%25\)%20and%20others%201.6%25.](https://nepaloutlook.com/karnali-province/#:~:text=The%20largest%20ethnic%20group%20in,1.7%25)%20and%20others%201.6%25.)
- Karki, S., Burton, P., & Mackey, B. (2020). Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. *Cogent Social Sciences*, 6(1), 1720555.
- Kc, D., Jamarkattel, D., Maraseni, T., Nandwani, D. and Karki, P. (2021). The effects of tunnel technology on crop productivity and livelihood of smallholder farmers in Nepal. *Sustainability*, 13(14), 7935.
- Kliem, L. and Sievers-Glotzbach, S. (2022). Seeds of resilience: The contribution of commons-based plant breeding and seed production to the social-ecological resilience of the agricultural sector. *International Journal of Agricultural Sustainability*, 20(4), 595-614.
- KPPC, (2020). *Nepali provincial planning; baseline and strategic options for Karnali Province* (Final report. http://kppc.karnali.gov.np/noticefile/PPC_Nepal_Regional_Report_Karnali_Province_-_Final_copy_1616311073.pdf

- Koirala, A. and Bhandari, P. (2018). Livestock insurance a tool to reduce economical loss of farmers from climate change related Hazards. *Insights Vet Sci*, 2, 005-008.
- Martínez-Mena, M., Boix-Fayos, C., Carrillo-López, E., Díaz-Pereira, E., Zornoza, R., Sánchez-Navarro, V., Acosta, J. A., Martínez-Martínez, S. and Almagro, M. (2021). Short-term impact of crop diversification on soil carbon fluxes and balance in rainfed and irrigated woody cropping systems under semiarid Mediterranean conditions. *Plant and Soil*, 467(1), 499-514.
- Ngosong, C., Okolle, J. N. and Tening, A. S. (2019). Mulching: A sustainable option to improve soil health. *Soil fertility management for sustainable development*, 231-249.
- NPHC, (2011). *National Population and Housing Census 2011*, National report. 1. <https://unstats.un.org/unsd/demographic-social/census/documents/Nepal/Nepal-Census-2011-Vol1.pdf>
- Rana, R. B., BK, P., GC, S., Bhattarai, H. K. & Shiwakoti, T. (2022). *Greening of value chains in karnali province: understanding farmers' knowledge, attitude and practice on climate resilient agriculture and agro-ecological farming*. Local Initiatives for Biodiversity Research and Development. https://libird.org/wp-content/uploads/GK_KAP_Study_Report.pdf
- Rehman, I.U., Islam, T., Wani, A.H., Rashid, I., Sheergojri, I.A., Bandh, M.M. and Rehman, S., (2022). *Biofertilizers: The Role in Sustainable Agriculture*. In *Sustainable Agriculture* (pp. 25-38). Springer
- Republica. (2021). *34 percent illiterate in Karnali Province*. myRepublica. <https://myrepublica.nagariknetwork.com/news/34-percent-illiterate-in-karnali-province/>
- Samuel, J., Rao, C. A. R., Raju, B. M. K., Reddy, A. A., Reddy, A. G. K., Kumar, R. N., ... & Prasad, J. V. N. S. (2021). Assessing the Impact of Climate Resilient Technologies in Minimizing Drought Impacts on Farm Incomes in Drylands. *Sustainability*, 14(1), 382.
- Shah, K.K., Modi, B., Pandey, H.P., Subedi, A., Aryal, G., Pandey, M. and Shrestha, J., (2021). Diversified crop rotation: an approach for sustainable agriculture production. *Advances in Agriculture*, 9, 1-9.
- Silici, L. (2014). *Agroecology: What it is and what it has to offer*. Issue Paper 14629IIED. London: International Institute for Environment and Development.

- Singh, R. P., Prasad, P. V. V. and Reddy, K. R. (2015). Climate change: implications for stakeholders in genetic resources and seed sector. *Advances in agronomy*, 129, 117-180.
- Upadhyaya, A. (2015). Water management technologies in agriculture: Challenges and opportunities. *Journal of Agri Search*, 2(1), 7-13.
- UN Nepal. (2021). Karnali Province. https://un.org.np/sites/default/files/doc_publication/2021-08/Karnali%20province_Humanitarian%20profile%202021.pdf
- Vijikumar, S. (2010). Agro-ecology for sustainable food security. *Indian journal of Natural Sciences*, 1(2), 85-89.
- Yang, T., Siddique, K. H. and Liu, K. (2020). Cropping systems in agriculture and their impact on soil health-A review. *Global Ecology and Conservation*, 23, e01118.
- Zhang, J., Van Der Heijden, M. G., Zhang, F. and Bender, S. F. (2020). Soil biodiversity and crop diversification are vital components of healthy soils and agricultural sustainability. *Frontiers of Agricultural Science and Engineering*, 7(3), 236