AGROECOLOGICAL PRINCIPLES AND ITS GAPS IN ADAPTION IN TERAI FARMING SYSTEM, NEPAL

Umesh K Mandal[1], Narendra R Khanal[2], Pashupati Nepal[3], and Kabita Kumari[4]

[1] Central Department of Geography, Tribhuvan University, Kathmandu, Nepal, umesh.mandal@cdg.tu.edu.np
[2] Nepal Geographical Society, Kathmandu, Nepal,nrkhanal.geog@gmail.com
[3] Central Department of Geography, Tribhuvan University, Kathamnadu, Nepal, nepalpashupati@yahoo.com
[4] Associated to Bernhardt & Arniko College , Kathmandu Nepal, kabitamandal2033@gmail.com

KEY WORDS: Gap, Institutionalization, Crop Diversity, Remittance Led Economy, Mechanization,Geospatial Technology

ABSTRACT

The present paper examines agroecological principles identified by FAO and its gaps by local farmers in terai farming system of Nepal. Household questionnaire survey, focus group discussion and KII were major tools of required information collection with regard to gaps of agroecology principles in their farming system. Agro-ecological principles have been examined with current farming practices carried out by local farmers. The gap analysis has been done with respect to ten agroecological principles: Efficient use of resources, balance use of chemical and organic fertilizer, , crop diversity, co-creation of knowledge, recycling of farm waste, synergy of crop, livestock and forestry ,human and social value, circular economy, cultural and food tradition, land and natural resource governance. 87.8 percent of households were used flooding method of surface irrigation against to principle of efficiency and deficit of water leading to wastage of water and constraining self-generating nutrient capacity of nature. 91.60 % of total cropped area was dominated by paddy - wheat based cropping system against to the principle of crop diversity. 72.4 % farmers used farm yard manure in limited temporal and spatial coverage area ranging from 0.03 ha to 1.69 hectare with the average of 0.39 ha and three months of year against the principle of recycling farm wastage to farm. Almost 14 % of households were having agroforestry practices against to the synergies of crop, livestock and forestry. Participation of women and youth in farming practices was found decreased due to remittance-led family economy. Geospatial technology-RS, GIS and GPS were extensively applied in preparation of all these agroecological resource maps required for agroecological studies and creation of their geo-database for sustainable land use planning in Nepal. Finally, the study necessitated the government policy to be instutionalized towards agroecological concept and hoped the methodology developed for this study could guide for achieving this goal.

1. INTRODUCTION

Nepal is a predominantly agro-economy based country where 73.9 % of people engaged in agriculture for their livelihood (CBS, 2011). Food sovereignty is one of fundamental sustainable goals of the country and it cannot be successfully achieved either by subsistence agriculture or by modern agriculture focusing on maximizing the quantity of food by planting monocultures and using high chemical inputs without knowing the ecological science for production on the one hand and farmer's capacity to understand those agroecological principles and its adaptation in farming system. Agro-ecology as a growing national and international multi-disciplinary science with the goal of achieving a sustainable agricultural ecosystem integrates scientific knowledge to traditional farming practices and experiences (Francis, 2003).

Agro-ecology has emerged as a discipline providing the basic ecological principles for study, design and manage agro-ecosystems making productive and conserving natural resources characterized as culturally sensitive, socially just and economically viable (Altieri, 1995). Modern agriculture in industrial countries maximizes the yield by using high-input technologies that generates environmental and health problems ultimately not serving the needs of producers and consumers. Agro-ecological farming supports the multifunctional dimensions of agriculture including food, jobs and economic welfare, along with social and environmental benefits, and important ecosystem services (Méndez, Bacon, and Cohen 2013).

Agro-ecology encompasses productivity, stability, sustainability and equitability as four system properties interconnected and integral to the success of an agroecosystems and it integrates through an interdisciplinary lens of natural and social sciences for understanding soil properties and plant-insect interactions and effects of farming practices on rural communities respectively along with economic and cultural factors determining farming practices (Conway, 1985).

Agro-ecology is a science, a practice and a movement (Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., and David, C. 2011; Wezel and Soldat. 2009; Wezel and Jauneau 2011) based on scientific and traditional knowledge bridging ecological and socio-economic aspects at various levels taking biological processes as agroecological principles sharing via farmer-to-farmer exchanges.

Social movements in rural areas are needed as bottom up approach of agroecology building (Laura, 2014). Creating alliances between rural and urban communities, agro-ecology is a pillar of the food sovereignty framework promoting the provision of land, water, seeds and other productive resources and economic opportunities to small farmers and landless people (WG & AF , 2015).

The final goal of agro-ecological design is to integrate components for improving biological efficiency and preserving biodiversity and the agro-ecosystem productivity and maintaining its self-sustaining capacity. The aim is to design a quilt of agro-ecosystems within a landscape unit, each imitate the structure and function of natural ecosystems (Gliessman, 2015). The present objective is to examine how far farmers adopted agroecological principles and strategies in their farming system and to identify the gaps in their farming practices.

2. MATERIALS AND METHODS

2.1 Study Area

The study area covers agricultural watershed, Khadokhola as case study ranging from Siwalik range in the north and terai plain in the south in eastern terai region as an agrarian region of Terai Farming System of Nepal . As a spatial extent of 253.32 sq km. (25332.0 ha), geographically, it ranges from 86°41'15" E to 86°51' 15" E and 26°26' 15 N to 26°40' 30" N with the altitudinal limit of 64 m -378 m above mean sea level. The location of study area is shown in Figure 1.The climate is sub-tropical that varies from south to north Khado khola river joins Koshi river near India boarder. At higher elevations, land cover is mixed forest which mainly consists of sal and sakhuwa (Shorea robusta) and crops include rice(Oryza sativa), wheat(Triticum aestivum) and maize(Zea mays).

The study area includes twelve types of land use /land cover as bamboo area, baren land, built up, bush, canal, cultivation, forest, grass, pond, river, sandy area, scattered tree areas and swamp area identified from satellite images, toposheet and google image. Being agricultural watershed, spatial extent is found dominated by agriculture consisting of 74.32 % of total geographical area of watershed and it is followed by forest (17.21%), sandy area (3.05%), bush (1.45 %), built up (0.91 %) etc in their decreasing magnitude. Spatially, agriculture land is confined to middle and lower watershed whereas forest is concentrated in upper part of watershed. The location of study area is shown in Figure 1.

2.2 Methodology

Field observation, household questionnaire survey, focus group discussion (FGDs), and Key Informants Interview (KII) methods were used for the collection of information on socio-economic status and farming practices including agriculture practices. Relevant information of farmers' household and their farming system were collected at Household and Farm Plot levels respectively, spatially distributed in upstream, middle and downstream part of watershed. Data/Information collected through household survey covered socio-economic characteristics, agriculture and livestock production agronomic practices including ploughing types, fertilizer use, irrigation system and weed control management.

Beside these the survey includes household income, expenditure and household food-security mentioned in questionnaire. All together 227 sampled households were interviewed from the watershed extending from up-down and east to west of the watershed. Remote Sensing (RS) as one of vital component of Geospatial technology was used for updatation of real time data as resource maps such land use land cover maps from satellite imageries. Similarly, Geographical Information System (GIS) as another major component of Geospatial technology was used for preparation of Agroecological maps and Global Position System(GPS) was extensively applied in verification of visually interpreted landuse land cover maps to the ground reality.

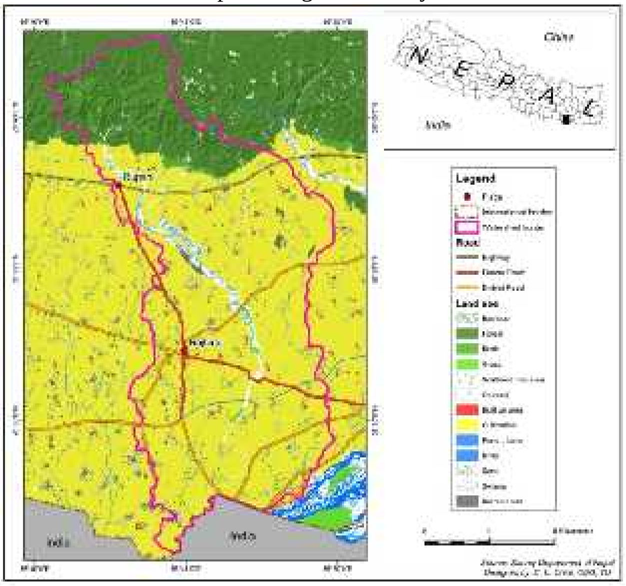

Figure 1: Location map of study area

.

3. RESULTS AND DISCUSSIONS

3.1 Agroecological Principles and Its Gaps in Terai Farming System

The present paper spells out the gaps between agro-ecology principles and its utilization by farmers in current farming practices in Terai Farming System. Among the plenty of concepts of agro-ecology from scientific discipline, practices to sustainable food system, FAO has identified 10 key elements derived from agro-ecology principles linking to elements of sustainable food system (Figure 2). In this alignment approach, here attempts have been made to explore gaps between these principles and its application in current existing use practices by farmers in Khadokhola watershed.

3.1.1 Efficiency

Efficiency in agroecological perspective as its element is understood as to optimize the use of natural resources within farming systems implying the use of inputs more efficiently meaning that fewer external resources are needed and the negative impacts of their use will be reduced. The essence behind this is not only protecting biodiversity but also in reducing the costs of production focusing much conventional agricultural research to enhance biological processes. In this sense, biomimicry as underlying principle of agro-ecology seeking to protect traditional farming systems has been emphasized because they involve strategies of production that mimic or imitate nature's own diversity (Benyus, 1997 and Harman, 2013). Furthermore, efficiency linking to biological processes is not a function of greater output per unit input rather than an emergent quality of an ecosystem using and generating its internal resources, and consequently it does not leak unused resources such as nutrients to the environment, causing severe pollution and also recognizing the value in connecting consumers with producers in short circuits, promoting a more efficient food value chain, including reducing of post-harvest food waste.

Looking this concept of efficiency and its application in current use practices by farmers in Terai Farming System (TFS), two major practices were found adopted against this that is flooding method of surface irrigation (87.8 % of households) in which water as precious resource and also scarce was found wastage while doing surface irrigation (Leach, 1976; Stout, 1998; Victor and Reuben, 2002; Smil, 2001; Pretty et al., 2003a; Townsend et al., 2003; Giles, 2005 and MA, 2005).

Similarly, secondly, heavy chemical fertilizer was found used by farmers that is against the concept of not to use heavy external inputs for maximizing yield rather self-generating nutrients. It is evident from the fact that 92.9, 90.9 and 76.8 % of the total surveyed farmers were found using DAP, Urea and Potash respectively as chemical fertilizer in their farm land to maximize production .

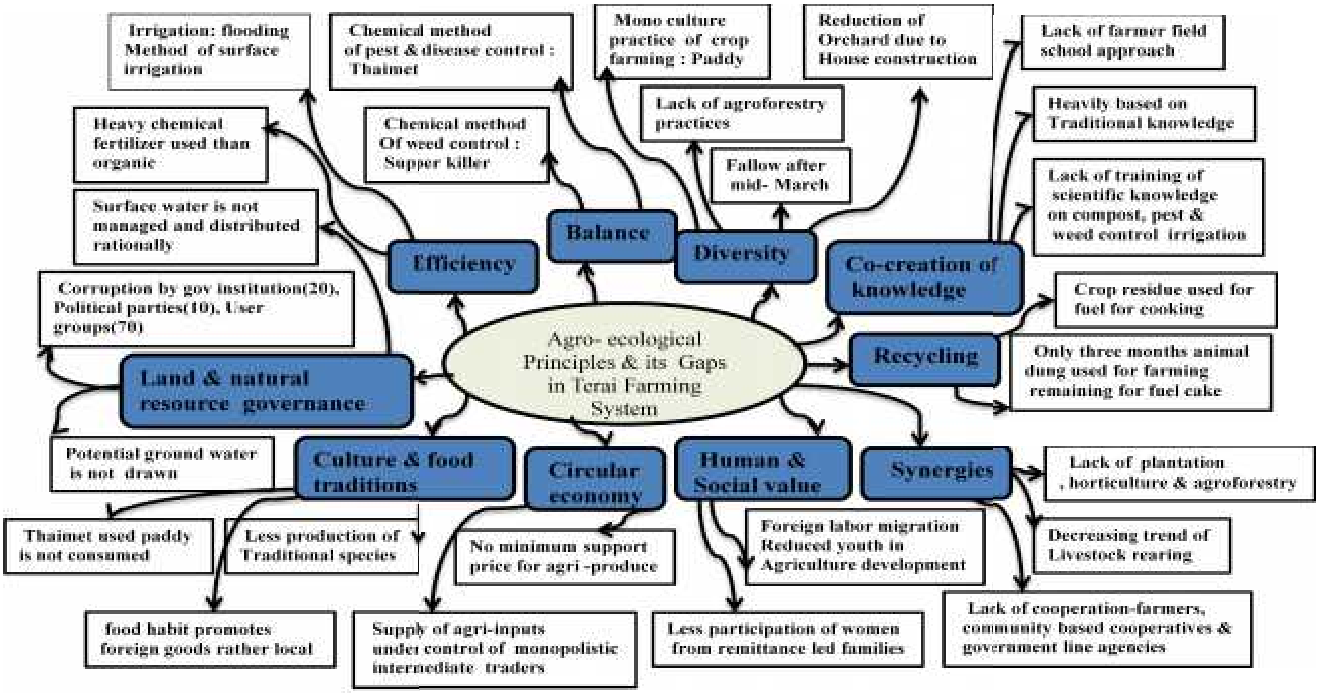

Fig. 1: Agroecological elements and its gaps in farming practices, Khadokhola watershed

3.1.2 Balance

Ecosystem principle or balance as underlying principle of agro-ecology is perceived as securing favorable soil conditions and self-regulation inside the food system implying that agro-ecology views the farm from a biological or ecosystemic perspective and eschews mechanistic or industrial models of productivity and efficiency. A fundamental principle of agro-ecology as the farming system is above all a human artifact and it exists within a broader ecosystem or watershed context. Furthermore natural ecosystems having the ability to self-regulate and attain a natural balance between pests, disease and natural enemies rather than using agrochemical (Gliessman, 1998) was emphasized and it views those pests or nutrients become limiting if conditions in the agroecosystems are not in equilibrium (Carrol, Vandermeer and Rosset, 1990; Altieri, Letourneaour and Davis, 1983).

As applying this principle of balance, farmers were found adding agrochemicals such as thaimet for pest and disease control and supper killer for controlling weeds as preventing farm strategy and to save their crops and loss of farm product. Such mechanism of pest and disease control makes imbalance of natural ecosystem and leads to germinate unwanted weeds and pest. In support of this, it was found that 95 % of farmers used agrochemicals for controlling pest, insect, disease and weeds and among all users, highest proportion as of 35 % farmers used thaimet.

3.1.3 Diversity

Polyculture or diversity as an underlying principle of agro-ecology has been interpretive as maximizing species and genetic resources across time and space within food systems in which conditions with different elements working in a harmonic way, each providing a specific ecological function (Francis, 1986; Vandermeer, 1989 and Altieri, 1995). These different conditions can be developed by increasing species and genetic resources, at multiple levels or strata also known as vertical diversity and by increasing spatial and temporal diversity. Such diversification ensures sustainable agriculture and reduces the risk of crop failure and other climate-related shocks even in areas experiencing water scarcity (Altieri, 1994 and Gliessman, 1998). Complex cropping systems having more crop species planted within sufficient spatial proximity that enhances yields due to result of competition or complementation among themselves (Francis, 1986 and Vandermeer, 1989). Temporal diversity as a agroecological strategy that incorporates into cropping systems for providing crop nutrients and breaking the life cycles of several micro-organisms and weed life cycles (Sumner, 1982). Similarly conceptualizing polycultures, agro-ecology privileges the production strategies of traditional polycultures over modern monocultures as a way to correct inequalities in agricultural research and extension services. Monocultures will also under-mine ecological methods of farming, such as rotations and polycultures (Hindmarsh, 1991). In global perspective, ninety one percent of the 1.5 billion hectares of cropland are under annual crops, mostly monocultures of wheat, rice, maize, cotton, and soybeans (Smil, 2001).

In this connection, farmers were found practicing monoculture - paddy and wheat dominated cropping pattern in summer and winter season respectively, temporal fallow of agriculture land (one-fourth of year) and decreased agro forestry. These practices do not signify the concept of crop diversity as an underlying principle of agro-ecology adopted by the farmers in Terai Farming System. To prove this, 97.78 % of surveyed farmers adapted paddy and wheat dominated cropping system and only 6.06 % farmers were involved in maize farming. Furthermore, only 14 % farmers were found adapting agro forestry practices in their entire farming system. If it is seen in terms of temporal diversity of crop production, Terai Farming System(TFS) is characterized as temporal fallow farming system in which one-fourth month of each year is not cultivated keeping fallow for open grazing for cattle and others. In spite of this, based on their knowledge or experience in terms of spatial diversity, relay cropping pattern such as paddy with linseed and wheat with mustard are found practiced along with nominal practice of legume crop farming. Traditional farming systems with varied degree of plant diversity as the form of polycultures (Clawson, 1985) are partially adopted. This agroecological strategy of minimizing risk in which several species and varieties of crops are planted that stabilizes yields over the longer period promoting diet diversity, and maximizing returns under low levels of technology and limited resources (Richards, 1985). Traditional multiple cropping systems share as much as 20 % of the world food supply (Francis, 1986).

3.1.4 Co-creation of knowledge or co-evolution

Co-creation of knowledge has been embedded from the sense of place as underlying principle of agro-ecology co-evoluting natural system to socio-economic system resulting as sustainability of agriculture (Reijntjes, Haverkort and Waters-Bayer, 1992; Vandermeer, 1995) and focusing local and traditional knowledge and innovation creating sustainable food systems based on local needs and local ecosystems. More specifically agro-ecology is knowledge-intensive that requires the development of both ecological literacy and decision-making skills in farmer communities rather than imposing decisions from top but sharing among farmers. Farmer Field School as a key approach that supports the scaling up of agro-ecology and builds upon the combination of both science and traditional knowledge in complementary processes in which different disciplines and actors are involved to find innovative solutions for sustainable production systems (Pretty, 1994 & Vandermeer, 1995) along with both formal and non-formal education sharing in a horizontal way.

Judging the farmers adopting practices in Khadokhola watershed with respect to principle of co-creation knowledge and sense of place, some of activities were found differing with the theoretical perspective mentioned in above immediate paragraph. These activities were characterized as non-farmer field school approach, traditional knowledge dominated practices and lack of scientific training on compost preparation, integrated pest and weed management and efficient irrigation management practices. The gap of integrating scientific knowledge to traditional experiences through appropriate training on specific practices was investigated by supporting the fact that 76.8 % farmers reported not to having scientific training and farmer field school visits from government respective institutions.

3.1.5 Recycling

Recycling as an underlying principle of agro-ecology considering socio-economic values of whole food system has been conceptualized as restore of natural fertility even on degraded land by reutilizing nutrients and biomass existing inside the farming system and increased use of renewable resources in order to promoting a healthy food system. Such recycling can be made by above ground-biomass maintaining fertility and below ground-functional biodiversity increasing microbial activity and nutrient recycles through biogeochemical process in existing soil profile. Recycling can be occurred at multiple levels augmenting within farms and landscapes by integrating livestock with crops aiding to achieve high biomass output and optimal recycling of using sunlight, soil nutrients and rainfall (Pretty, 1994 and Pearson & Ison, 1987).

Farmers in Khadokhola watershed were also been examined keeping this principle in mind and three activities were found associated with this. They are: use of farm wastage, use of cow dung and decreasing trend of animal rearing. The essence of recycling is to get back farm wastage to farm for maintaining natural fertility but in case of watershed, the average farm size of using farmyard manure is only 0.39 ha by 72.5 % of total farmers in the watershed. Crop residue included in farmyard manure was found used for fueling for cooking food rather than getting back to farm for enhancing fertility. Similarly cow dung of only three months of the year was being got back to farm land because of lack of time and rainy season unsuitable for making fuel cake for cooking.

3.1. 6 Synergie

Under synergie as an principle of agro-ecology, it has been designed in integrated way of ecological interaction among crop, animal and forestry promoting optimum ecological functions for self-regulation in foods system (Altieri, 1995). It considers the minimal dependence on high agrochemical and energy inputs that emphasizes complex agricultural systems of mechanisms to sponsor their own soil fertility, productivity and crop protection (Altieri and Rosset, 1995). In this agricultural system, trees are grown together with annual crops and/or animals that results for enhancing complementary relations between components increasing multiple use of the agroecosystems (Nair, 1982) along with leguminous or other annual plant species under fruit trees for the purpose of improving soil fertility in order to enhance biological control of pests, and to modify the orchard microclimate (Finch and Sharp, 1976).Natural pest regulation, crop productivity, and community empowerment are to be synergized in the partnerships in which food systems are sustained by cooperation, not competition emphasizing the idea of agriculture embedded in multiple systems: biophysical, social, political-economic, and cultural as an underlying principle of agro-ecology.

If this underlying principle of synergie was overlayed on existing current farmers practices, three practices were investigated in Khado khola watershed: decreasing trend of plantation because of habitation, decreasing trend of livestock rearing because of labor shortage and lock of coordination between farmer community and line agencies service providers. It is evident from the fact that 58 % farmers reported as decreasing trend of livestock rearing in Khadokhola watershed. Line agencies were not found cooperated or integrated to farmer's community in terms of providing services, knowledge and training. In spite of this, there is cooperation among the farmers for exchanging improved seeds varieties as the same condition found in Thailand and Indonesia (Grigg, 1974).

3.1. 7 Human and social value

As an underlying element of agro-ecology generated from its principle, it includes the cultural norms and tradition, innovation and knowledge of local communities and livelihoods, favoring social dynamics and plays a critical role in determining our food systems that focuses on women's and youth's role in agricultural development. Beside this, agro-ecology places an emphasis on human and social values of farmers and communities as the heart of food production, and on sharing this knowledge to empower communities (Gliessman 2020). Recognizing the human and social values within food systems is vital to achieving food security and nutrition.

Evaluating this principle of agro-ecology with the farming practices carried out by farmers in Khadokhola watershed, two characteristics were investigated: less participation of youth in farming activities due to foreign labor migration and similarly decreasing proportion of women participation in agriculture activities from those remittance-led families. Data collected during the field survey shows that 40 % households reported to have labor migration from 1-4 family members working in foreign gulf countries and are receiving remittance as mean of NRs 32981 (US $ 271.14) per month. Women from remittance received families were not found willing to work in farmland in return, they were transferred to municipal towns for comfort life and better education for children.

3.1.8 Circular economy

It is one of fundamental elements of agro-ecology associated with the concept of local solutions and local markets creating virtuous cycles incomes-monetary and non-monetary needed to be fair and sufficient to sustain livelihoods ensuring food security and well-being. Multifunction as an agroecological approach to agriculture producing goods and services in a fair and sustainable way, promoting local economies (Thrupp, 1998 and Toledo, 1995), goes beyond the production and consumption of goods and services alone but also seeking fair solutions based on local needs, resources and capacities, creating equal and sustainable markets. Furthermore, circular economy focuses to strengthen short food circuits with a decreased number of intermediaries, increasing the incomes of food producers and keeping a fair price for consumers.

If this concept of agro-ecology is judged with the existing farming practices in Khadokhola watershed, circular economy was not found practiced since local markets providing agriculture inputs were not fair and as a sustainable way in return, it was dominated by intermediate monopolistic traders and their main motto is to get more benefits by taking inputs such as chemical fertilizer and improved seeds from government line agencies in cheaper price and selling to farmers in expensive rate. Beside this, local traders create spike markets of lacking inputs in the needy time of farming activities. In addition to, farmers as a consumer have to sell their agriculture product in low price when they have more surpluses and have to buy in expensive price in the condition of shortage of same product. It is usually seen because of lack of determination of minimum support price of agriculture produce and controlling of local markets.

3, 1.9 Cultural and food traditions

As an underlying principle of agro-ecology, it plays an important part linking existing agriculture practices and healthy, diversified and culturally appropriate diets, good nutrition ensuring the healthy ecosystems. As a core part, agriculture plays a central role in society connecting cultural food habit and product type in their farm. Disconnection between foods habits and culture has contributed to a situation of malnutrition and obesity even though there is enough food to feed its entire population. Thus, increasing production alone is not sufficient to eliminate hunger and food insecurity. Agro-ecology plays an important role in integrating tradition and modern food habits, in such a way that promotes healthy food production and consumption along with supporting the right to adequate food.

In this connection, three agriculture farming practices were reported by the farmers in Khadokhola watershed: thaimet used paddy not used by farmer themselves, less production of traditional low yielding crop species and local food habit promoting foreign goods rather than local. Pesticides used production was not consumed mainly by farmer themselves; it was for high return by selling in the market. With the aim of getting more yield, traditional crop species were less prioritized as compared to high-yielding species. Food habit of local community was found changed with the time and relatively not matched or compatible with what they produce in their own farm.

3.1. 10 Land and natural resource governance

As a principle of agro-ecology, resource governance is implied as the process of collective decision-making regarding the use of natural resources in sustainable way and equitable access by private and public users. Such decision derives the fact that one person's use of natural resources impacts upon other people as environmental externalities ranging from the local, the regional, the national or global (Cole, 2002). A part from this, agro-ecology recognizes and supports the smallholder and marginal food producers as an efficient managers and guardians of natural and genetic resources that ensure a fair and inclusive food system and having access to land, water (surface and groundwater) (Deborah & Niels 2018). Furthermore, agro-ecology ensures land tenure as fundamental to maintaining a functional and sustainable food system.

In regard to statement mentioned above, different agriculture farming activities against to resource governance were practiced by the farmers in Khadokhola watershed. They are: corruption in maintenance of both Koshi-western and Chandra Canal, India led water distribution system, river embankment first control by landlord and then Maoist and Maoist led community forestry, land tenure system. 12.5 % farmers reported that they have dual ownership by landlord and tenants. Governance was not found in maintaining irrigational canals and local level infrastructure development programs. Hierarchical level of stakeholders involved in corruption represented 10% by local government institutions, 20% by local political parties and 70% by user groups.

4. CONCLUSIONS

Agroecological gaps were explored based on principles and their adaptation in current existing use practices by farmers in Khadokhola watershed. Flooding as a faulty method of surface irrigation and high amount use of chemical fertilizer were found practiced in agriculture watershed in Terai Region against principle of efficiency leading to wastage of water and to reduce self-generating nutrient capacity of nature respectively. Paddy and wheat based cropping system dominated by mono-culture was practiced by farmers against the principle of polycultures or crop diversity. Integration of scientific knowledge to traditional experience was found as one of major gap in farming system of Terai Region due to lack of scientific training and farmer field school visits. Farm yard manure including crop residue and animal dung were mostly used for fueling for cooking food rather sending back to farm leading to break recycling of waste to nutrient for crop. Integration of crop, livestock and forestry in farming system of Terai was found sporadic due to decreasing trend of livestock rearing and orchard hindering optimum ecological functions for self-regulation in foods system. Women and youth as one of nature conservers was found less participated in existing farming system of eastern terai region due to outgoing youth migration and remittance-led family economy. Looking to circular economy, local markets were not fair and badly controlled by intermediate traders in monopolistic nature of market. In connection to cultural and food tradition, pesticide led paddy product was not consumed by farmer themselves and less production of traditional crop varieties due to low yielding and local food habit was found to be promoting foreign goods rather than local own product. With respect to land and natural resource governance, corruption in maintenance of both Koshi-western and Chandra Canal, India led water distribution system, river embankment first control by landlord and then Maoist and Maoist led community forestry, land tenure system were major activities being practiced against resource governance. Dual ownership by both landlord and tenants and hierarchical level of stakeholder's involvement in corruption of local level infrastructure maintenance and development are to be eradicated for ever for establishing resource governance.

Agroecological resource maps required for agroecological studies and creation of their geo-database were performed using geospatial technology for sustainable land use planning in Nepal Finally, the study necessitated the government policy for establishing *Agroecological Institutions* towards understanding the agroecological concept, principles, strategies and designs and their implementation in Terai Farming System to be a country independent in food production for growing population and establishing food sovereignty in the country and hoped the findings derived from this study could guide for achieving this goal.

REFERENCES

Altieri, M.A., 1995. Agro-ecology: The science of sustainable agriculture. Boulder, Westview Press.

Altieri, M.A., 1994. Biodiversity and pest management in agroecosystems. New York: Hayworth press.

Altieri, M.A., Letourneaour,D.K., & Davis, J.R., 1983. Developing sustainable agroecosystems. BioScience 33,pp: 45-49.

Altieri, M.A. and P.M. Rosset 1995. Agroecology and the conversion of large-scale conventional systems to sustainable management. International Journal of Environmental Studies 50: 165-185.

Benyus, J. 1997. Biomimicry: Innovation Inspired by Nature, New York: Harper Perennial.

Carrol, C. R., Vandermeer, J.H., & Rosset, P.M., 1990. Agro-ecology. McGraw Hill Publishing Company, New York.

CBS. 2011. Nepal Living Standards Survey 2010/11 Statistical Report Volume Two. Central Bureau of Statistics, National Planning Commission Secretariat, His Majesty's Government of Nepal.

Clawson, D.L., 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. Econ. Bot. 39,pp:56-67.

Cole, D.H., (2002). pollution and property: comparing ownership institutions for environmental protection. Cambridge University Press, Cambridge.

Conway, G.R., 1985. Agroecosystem analysis. Agricultural Administration, 20,pp: 31-55. 118, DOI: 10.1300/J064v22n03_10.

Finch, C.V. & Sharp, C.W., 1976. Cover crops in california orchards and vineyards. Washington, D.C., USDA Soil Conservation Service.

Francis, C.A. 1986. Multiple cropping systems. MacMillan, New York.

Francis, C., 2003. Agro-ecology: The ecology of food systems.Journal of Sustainable Agriculture 22.3 Retrieved 16 June 2010 from http://en.wikipedia.org/wiki/Agro-ecology.

Giles J. 2005. Nitrogen study fertilizes fears of pollution. Nature 433, 791

Gliessman, S.R. 2000. Field and Laboratory Investigations in Agroecology. Lewis Publishers, Boca Raton, Florida.

Gliessman, S. R. 2015. Agroecology: The ecology of sustainable food systems, third ed., 371. NewYork: Taylor & Francis.

Gliessman, S. R., 1998. Agro-ecology: ecological processes in sustainable agriculture. Ann Arbor: Sleeping Bear Press, Retrieved 16 June 2010 from http://en.wikipedia.org/wiki/Agro-ecology .

Grigg, D.B., (1974). The Agricultural systems of the world: an evolutionary approach. Cambridge, Cambridge University Press.

https://doi.org/10.5194/isprs-archives-XLVIII-1-W2-2023-1445-2023

Harman, J. 2013. The shark's paintbrush: biomimicry and how nature is inspiring innovation, Ashland: White Cloud Press.

Hindmarsh, R., 1991. The flawed "sustainable" promise of genetic engineering. The Ecologist 21,pp: 196-205.

Laura Silici, 2014. Agroecology: What it is and what it has to offer . IIED Issue Paper. IIED, London.

Leach, G. 1976. Energy and Food Production. IPC Science and Technology Press, Guildford and IIED,London.

MA (Millennium Ecosystem Assessment). 2005. Ecosystems and Well-Being. Island Press, Washington DC.

Méndez, V.E., Bacon, C.M., & Cohen, R. 2013. Agro-ecology as a transdisciplinary, participatory, and action-oriented approach. Agroecol. Sustain. Food Syst. 37,pp: 3–18

Mette Vaarst, Arthur Getz Escudero, M. Jahi Chappell, Catherine Brinkley, Ravic Nijbroek, Nilson A.M. Arraes, Lise Andreasen, Andreas Gattinger, Gustavo Fonseca De Almeida.

Deborah Bossio & Niels Halberg 2018. Exploring the concept of agroecological food systems in a city-region context, Agroecology and Sustainable Food Systems, 42:6, 686-711, Taylor & Francis Group, LLC DOI: 10.1080/21683565.2017.1365321.

Nair, P.K.R. 1982. Soil Productivity Aspects of Agroforestry. ICRAF, Nairobi.

Pearson, C.J., & Ison, R.L. 1987. Agronomy of grassland systems. Cambridge University Press, Cambridge.

Pretty, J.N.1994. Regenerating agriculture. London, Earthscan Publications Ltd.

Pretty J, Mason C F, Nedwell D B and Hine R E. 2003a. Environmental costs of freshwater eutrophication in England and Wales. Environmental Science and Technology 37(2), 201-208

Richards, P. 1985. Indigenous agricultural revolution. Boulder, Westview Press.

Reijntjes, C.B., Haverkort & Waters-Bayer,A. 1992. Farming for the future. London, MacMillan Press Ltd.

Smil V. 2001. Enriching the Earth. MIT Press, Cambridge MA

Stout B A. 1998. Energy for agriculture in the 21st century. In Waterlow J C, Armstrong D G, Fowden L and Riley R (eds). Feeding the World Population of More Than Eight Billion People. Oxford University Press, New York and Oxford

Sumner, D.R. 1982. Crop rotation and plant productivity. In M. Recheigl,(ed.). Handbook of Agricultural Productivity, Vol. I CRC Press, Florida.

Thrupp, L.A. 1998. Cultivating diversity: agrobiodiversity and food security. Washington, DC, World Resources Institute.

Toledo, V.M. 1995. Peasantry, agroindustriality and sustainability. Interamerican Council for Sustainable Agriculture. Working Paper 3. Michoacan, Mexico.

Townsend A R, Howarth R W, Bazzaz F A, Booth M S, Cleveland C C, Collinge S K, Dobson A P, Epstein P R, Holland E A, Keeney D R, Mallin M A, Rogers C A, Wayne P and Wolfe A H. 2003. Human health effects of a changing global nitrogen cycle. Front Ecol Environ 1(5), 240-246.

Vandermeer, J. 1989. The Ecology of Intercropping. Cambridge University Press, Cambridge, 237p. https://doi.org/10.1017/CBO9780511623523

Vandermeer, J.1995. The ecological basis of alternative agriculture. Annual Review of Ecological Systems 26,pp: 201-224.

Victor T J and Reuben R. 2002. Effects of organic and inorganic fertilizers on mosquito populations in rice fields of southern India. Med Vet Entomol. 14, 361-368.

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. 2011. Agro-ecology as a science, a movement and a practice. Sustain. Agric. 2011, 2, pp: 27–43.

Wezel, A., & Soldat, V. 2009. A quantitative and qualitative historical analysis of the scientific discipline agro-ecology. International Journal of Agricultural Sustainability 7 (1): 3-18. Retrieved 23 may 2010 from HYPERLINK http://en.wikipedia.org/wiki/Agro-ecology

Wezel, A., and C. David. 2012. Agroecology and the food system. In Agroecology and strategies for climate change, ed. E. Lichtfouse, Vol. 8, 17–34. Sustainable Agriculture Reviews. Dordrecht, The Netherlands: Springer.

Wezel, A., and J. C. Jauneau. 2011. Agroecology—Interpretations, approaches and their links to nature conservation, rural development and ecotourism. In Integrating agriculture, conservation and ecotourism: Examples from the field, eds. W. B. Campbell and S. López Ortiz, 1–25. Issues in Agroecology—Present Status and Future Prospectus 1. Dordrecht, The Netherlands: Springer.

WG & AF. 2015. The seven pillars of sustainable, small-scale farming and food sovereignty in the global North-South. A position paper of the Working Group on Agriculture and Food (WG A&F) of the German NGO Forum on Environment and Development