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Unravelling Resilience in Homestead Agroforestry Practice: A Review

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ABSTRACT

The unprecedented climate changes are impacting agrarian livelihoods worldwide. Since lives heavily depend on agriculture, alternative farming mechanisms should be promoted to counter the effects. Homestead agriculture has a long tradition of compensating for the vagaries of weather and offering subsistence to the growers, at the same time conserving the ecosystem. The resilience of the practice is reviewed in this article with a focus on agroforestry's unique characteristics, high biodiversity and multifaceted benefits as a land use system. A better understanding of the resilience potential of the homesteads to varying environments is important to integrate the system into the agricultural production scenario of nations, thereby bridging the unpredictable events of climate change. The best illustration of an effective indigenous resilience strategy is the tenacious persistence of homestead farming across millions of hectares.

Key words: Agroforestry, Climate, Homegarden, Multiple services, Multistoreyed configuration, Resilience.

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Many modifications have been made in the process of transforming agriculture into the commercial farming of today, all with the goal of achieving national economic security and self-sufficiency in production. Science has completely changed how crop management is done. Precision agriculture, which uses robotics and GPS to reduce labor-intensive farming, has become more complex and less labor-intensive (Kushwaha, 2019). However, homestead agriculture has always been a kind of farming for the family in and around the farmer's residences, running concurrently with this. In many states and/or nations, homestead farming still dominates the agricultural landscape. According to Chandrashekara and Baiju (2010), tropical home gardens are conventional agroforestry systems with a complicated structure and a variety of uses. A homegarden is a pluralistic land use order in the humid tropics and as a land management system; it has been well-developed in south, south-east Asia and Latin America (Kumar, 2015). They are regarded as 'epitomes of sustainability' throughout the tropics (Torquebiau, 1992) and also considered as microenvironments within the agroecosystem to preserve the function and resilience of the larger ecosystem (Engels, 2001).

The ecological characters/functions (Soemarwoto and Soemarwoto, 1984), structural diversity (Blanckaert *et al*., 2004), sustainable agroforestry nature (Kumar and Nair, 2006), litter and nutrient dynamics (Upadhyaya *et al*., 2012), carbon sequestration potential (Kumar, 2006), enigmatic nature (Kumar and Nair, 2004), germplasm banks and key sites for domestication (Huai and Hamilton, 2009), multi faceted land use (John, 2014) *etc*. of varying homesteads have been documented. As these systems are affirmed as the origin of agriculture in a region (Gorman, 1971) and are described as 'steady-state' systems by ecologists (Kumar and Nair, 2004). The ensuing changes in climatic events and the impacts on agricultural production have necessitated an analysis of homestead production units for their adaptability and ability for agrarian livelihood security. An attempt has been made in this review to project the unique resilient nature of homesteads from the available literature. For an easy understanding, the first part of the review discusses the history, definitions, concept and characteristics and the later part focusses on the resilient nature of the homesteads.

Methodology

Homestead Agro forestry system is a unique feature of Kerala. For the proper understanding and exploitation of knowledge about Agroforestry and Homesteads, we have collected more than 300 review articles from online and offline sources. After preliminary screening, 200-250 papers were selected which were found relevant for the topic. The papers were assorted based on the existing information available and characteristics of homestead and correlated with each other.

Homesteads revisited

Homestead farming or home garden is an age-old farming practice prevalent in various parts of the world. Kumar and Nair (2004) see home gardens as the oldest land use activity, next only to shifting cultivation. Evidences show that this farming has been practised from time immemorial.. For instance, Indian epics *Mahabharata* and *Ramayana*, mentioned the presence of *Ashok Vatika* (Puri and Nair, 2004). It is also referred to in the great book of Hindu aesthetics, *Kamasutra* by *Vatsyayana* which was written during 3rd to 4th century AD and also in the travelogue by the Muslim traveller, Ibn Battuta (1325-1354) who described the cultivation of *kalpavriksha* (*Cocos nucifera*) and black pepper (*Piper nigrum*) along the houses of Malabar coast of Kerala (Randhawa, 1980).

Varied definitions for homestead farming have been reported and a few are discussed here. Nair and Sreedharan (1986) defined homestead as an operational farm unit in which a number of crops (inluding tree crops) are grown with livestock, poultry and/or fish production mainly for the purpose of satisfying the farmer's basic needs while Karyono (1990) described homegarden as a clearly bounded piece of land cultivated with a diverse mixture of annual and perennial crops and on which a house is built. According to Alam and Furukawa (2010), this farming system involves a deliberate planting and management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, livestock, within the compounds of individual houses. All definitions emanate the fact that it is farming by the family, for the family and within the household premises.

Concepts and key characteristics

Homesteads are agroforestry systems within the household premises. The motto of the homestead is 'a mixed farm with diversified enterprises where dependence is not on a single enterprise'. Ninez (1987) has described the key characteristics of homesteads (Table 1) as follows:

Nevertheless, Isaac *et al*. (2019) based on the participatory analysis of the homesteads in southern Kerala, have reported that the present day homesteads have come a long way from the traditional ones. Nowadays they are more complex and diversified in tune with the advances in agricultural technologies with the inclusion of apiary, fish ponds, azolla and biogas units, composting units, mushroom sheds, terrace gardens, vertical farming units, polyhouse/ rain shelters, water harvesting structures *etc*.

Resilience

Recognition of the impending threats that climate change could have on agricultural production has sparked a desire among stakeholders to strengthen the resilience of agricultural systems (Lin, 2011). The concept has been studied and reported in a wide range of ecosystems, from coral reefs to forests (Chapin *et al*., 2004), but documentary evidences in homestead farming systems are comparatively less.

Resilience can be conceptualized as the ability of farming systems to cope with challenges (Bullock *et al*., 2017). According to Cambridge University Press (2008), it is the quality of being able to return quickly to a previous good state after problems.

Nelson *et al*. (2007) defined climate resilience as the ability to adapt, reorganize and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts.

Features that make homesteads resilient

Agroforestry characteristics

The different features of an agroforestry that makes homestead resilient include ecological attributes, environmental attributes, multi-storeyed configuration, species diversity (Table 2).

Number of species may vary from one country to another and Table 3 shows the species diversity of selected countries/state.

Climate regulation

Homestead systems have the potential to regulate the climate on a local and global scale. On the local level, the dense vertical structure of trees helps in controlling microclimatic fluctuations by influencing the air temperature, radiation flux, soil moisture and wind speed (Rao *et al*., 2007) and macroclimate regulation is through carbon (C) sequestration as the woody biomass offers potential for C storage (Mohri *et al*., 2013).

Regulation of microclimate

The homegardens are reported to have more favourable microenvironments with lower soil and atmospheric temperature and higher relative humidity than the open environment (Gajaseni and Gajaseni, 1999). This results in less soil evapotranspiration and more soil water retention which in turn enhances the soil biological activity.

Shade trees buffer high and low air temperatures by as much as 5°C (Beer *et al*., 1998). Similarly, soil temperature variation beneath tree canopies and in open soil temperatures was 2-3.5°C (Isaac, 2001), the higher temperatures being in the open. Significantly lower air temperature (0.31-0.90°C) was observed inside the

Table 1: Key characteristics of homesteads.

Concept	General practice
Species density	High
Species type	Staple, vegetable, fruits
Production objective	Home consumption
Labor source	Family (female, elderly children)
Labor requirements	Part-time
Harvest frequency	Daily, seasonal
Space utilization	Horizontal and vertical
Location	Close to dwelling
Cropping patterns	Irregular, row
Economic role	Supplementary
Technology	Simple hand tool
Inputs-cost	Low
Distribution	Rural and urban
Skills	Garden-horticultural
Assistance	None or minor

Table 2: Agroforestry characteristics that makes homestead resilient

Features	Specific characteristics	Quantification of the impact of the character reported in pre column	Reference
Ecological attributes	Comparison of ecological attributes of natural climax forest, homestead agroforestry and monocropping	Homestead systems resemble the natural forests. Quality of agroforestry systems on homesteads is increasingly improving and the homesteads are sustainable.	Kumar and Nair (2004)
Multi-storeyed configuration	Multi-layered, forest-like vegetation. Annual lopping of jack tree	Reduces soil erosion due to rain and wind. Improvement in stem form and better timber quality.	Christanty *et al.* (1986) Elevitch and Manner (2006)
Species diversity	Agrobiodiversity	Provide contingency under unfavourable conditions. Buffering against shifting rainfall and temperature patterns Important ethnic agro-ecosystem in the region.	Swiderska *et al.* (2011) Altieri and Koohafkan (2013) Das and Das (2020)
Environmental protection	Reduced soil erosion	Canopy and root architecture and the litter layer, act as multi-layer defense mechanisms against the impact of the falling rain drops.	Torquebiau (1992)
	2004 Indian Ocean Tsunami	Live fence vegetation had made a difference in the impact of the Tsunami waves in the homesteads in Sri Lanka.	Harvey (2006)
	Windbreaks	Residents of Archipelago, Japan highly valued fukugi trees (*Garcinia subelliptica*) in homestead as windbreaks.	Chen and Liang (2020)
	Detoxification of pollutants	The use of plants to decontaminate polluted soils is one of the environmental services.	Atangana *et al.* (2014)
	Suppression of pathogenic organisms, weeds.	The suppressive mechanisms by rhizosphere bacteria include production of antibiotics, siderophores, volatile organic compounds, hydrolytic enzymes *etc*.	Sindhu *et al.* (2009)
	Maintain or increase soil fertility	Intensive management is done in the homegardens.	Salim *et al.* (2018)
	Adoption of soil health management practices	Narrow down the requirement for agro-chemicals in controlling invasive pests and diseases.	Bandyopadhyay *et al.* (2016)
	Water recharge in sacred grooves	Sacred groves marks a unique entity in the Kerala *Tharavad* (homesteads) of yesteryears, include ponds and streams that store rain water and also act as source of water for the different organisms.	Chandrashekara *et al.* (2018)

Table 3: Species diversity of some homesteads in selected countries/state.

Country/State	Number of species	Reference
Papua New Guinea India	85	Thaman 1985
Kerala	>130	Jose and Shanmugaratnam, 1993
Assam	122	Das and Das, 2005
Costa rica	46	Zaldivar *et al.*, 2002
Cuba	101	Wezel and Bender, 2003
Ethiopia	64	Tolera *et al.*, 2008
	49	Birhane *et al.*, 2020
Brazil	154	de Freitas *et al.,* 2020

homegarden in summer compared to outside the homegardens in China (Liu *et al*., 2019). Relative Light Interception at various strata in homegarden of Cihampelas, West Java was studied by Christanty (1981) and observed 6, 10, 64 and 20% of light interception in bottom, third, second and top layer, respectively.

Regulation of macroclimate

Global warming effects are changing the rhythms of climate that all living things have come to rely on. Carbon dioxide is regarded as the major contributor to the greenhouse effects and hence strategies to reduce the concentration in the atmosphere is coveted. The forest-like structure and composition endorse high C sequestration potential to the homegardens (Kumar, 2006). Albrecht and Kandji (2003) explicated that the quantity of carbon stored is dependent on many factors like structure and function of the components and nature of the system which are controlled by environmental variables. For example, the average carbon storage in semiarid, subhumid, humid and temperate agroforestry practices has been been estimated to be 9, 21, 50 and 63 Mg C ha^{-1} (Schroeder, 1994). The influence of a variable like elevation on carbon sequestration has studied by many (Birhane *et al*., 2020).

According to Nair *et al*. (2010), on an average 0.29-15.21 Mg C ha^{-1} yr^{-1} is stored in trees and 30 - 300 Mg C ha^{-1} yr^{-1} in soil. Carbon sequestration potential agroforestry homegarden in different elevations in southern Ethiopia studied by Birhane *et al*. (2020) led to the observation that the homegradens in the upper elevations showed higher biomass C and soil organic carbon than that in the lower elevation.

Soil management

Soil health and sustainable management are crucial for any successful crop production programme. The vulnerability of soil to the different management practices brings about changes in its properties which in the long term affect the productive capacity. Soil resilience is defined as the capacity of the soil to recover its functional and structural integrity after disturbances (Herrick and Wander, 1998). It is a key soil attribute that describes the capacity of the soil to recover from continuous and persistent anthropogenic stresses and in its absence, all managed soils would have ceased to produce ecosystem services long ago (Blanco-Canqui and Lal, 2010).

Increased organic matter and soil organisms

Magdoff and Weil (2004) reported improvements in water retention capacity, infiltration and surface soil aggregation with increased organic matter. The various sources of organic materials added in homesteads include, leaf litter, crop residues, tree loppings, root sloughings and exudates, household biowastes, animal excreta, poultry droppings *etc*. Intensive use of organic manures and resource flow among the components ensure the resilience in homesteads (Isaac *et al*., 2019).

Cycling of nutrients

Nutrient cycling is more efficient in multistrata agroforestry systems than in monoculture plantations (Nair *et al*., 1999). Presence of trees and shrubs especially N fixing, with deep root system and mycorrhizal associations ensure an almost closed nutrient cycling pathway in the system.

Replenishment of nutrients taken up or removed by the crops from soil forms the basis for soil nutrient management. An *in situ* mechanism of nutrient recycling is the most opted solution for sustained production. Nutrient cycling is inherent to homesteads. Dynamics of litter production, decomposition and subsequent bioelement release in the soil endow sustainability to homesteads (Heal *et al*., 1997).

Trees (throughfall, litter fall and stem flow), crop residues, N fixing trees, animal/poultry manures and household biowastes add nutrient inputs to the soil nutrient pool in addition to organic matter enrichment. Nutrient cycling in homesteads is said to be closed (Nair *et al*., 1999) and efficient (Gajaseni and Gajaseni, 1999).

Abraham (1997) investigated the annual nutrient additions (litterfall, throughfall, stem flow and organic manures) and removal in a 0.48 ha homestead and reported a net gain of 33.66, 16.18 and 45.17 kg NPK ha^{-1}. Comparing the soil properties in homesteads, Kumar and Nair (2004) explicated that porosity was 14-23% more, bulk density, 12-20% less and particle density, 2-5% less in the homestead compared to adjacent open area.

Soil fertility improvements were attributed to the deep rooted trees and the subsequent cycling of nutrients through litter, branches and fruits and the data emanated imply that nutrient cycling in the homegardens. Seneviratne *et al*. (2006) opined that it is not just the biodiversity but the plant structural diversity that which decides efficient nutrient cycling in homegardens. The multi strata canopy and root system assure annidation in space for the growth resources *viz*. sunlight, water and nutrients. Comparative studies on the microbial counts in open and homegarden soils have revealed higher biological counts in the latter (Isaac, 2001). Similarly higher fungal and bacterial population was also observed in traditional agroforestry systems of Northeast India (Tangjang and Arunachalam, 2009). Soil improvement in 15 indigenous home gardens of different ages (1-40 years) in the savanna of Roraima, Brazil was investigated by Pinho *et al*. (2010). Results showed that soil organic matter and P, K, Ca and Mg concentrations increased over time in homegarden soils, in comparison with the levels found in the adjacent savanna.

Multiple production system

Food and nutritional security stands above all the considerations for a resilient farming system. The homestead system succeeds in satisfying the basic needs of human life, food, along with the multiple services of protection, income and sustainability. Selected trees, shrubs and herbs/agricultural crops are grown in homesteads for edible products and cash income, as well as for a variety of outputs that have both production and service values including aesthetic and ecological benefits. The multi-species production systems entailed in the homesteads are considered model systems for designing sustainable agroecosystems (Chandrashekara and Baiju, 2010). Subsistence output supports the farmer and his family in the form of daily food items and his domestic animals in the form of fodder derived from the by-products of the crops grown.

Species diversity in agroforestry homegardens of southern Ethiopia (Fig 1) was studied by Abebe *et al.* (2010). Presence of fruit crops (pineapple) fodder crops (congo signal grass, hybrid napier) and azolla were also observed in homesteads of Kerala (Anilkumar *et al*., 2017).

Traditional and indigenous knowledge

The resilience of homesteads is greatly enhanced by indigenous traditions and knowledge (Mukhopadhyay, 2009). It is currently acknowledged that one of the most important tools in the battle against climate change is traditional and indigenous knowledge (ITK), which may be used to manage habitats and use resources wisely. Understanding, in addition to maintaining the farming techniques, can help prevent plant genetic erosion and environmental degradation. Using ITKs can help achieve sustainable food security, preserve plant and animal diversity and conserve soil qualities. Homesteads, which are associated with the cultivation of native and local types and species, medicinal and herbal plants and trees, utilization, germplasm conservation, management techniques, seed storage procedures, animal management and weather forecast indicators, can be thought of as the dwellings of ITKs. Kala (2010) underlined the importance of traditional ecological knowledge of homegarden farmers in conserving the threatened wild species in homegardens in the study conducted in Pachmarhi Biosphere Reserve in India.

Socioeconomic role

The subsistence nature of the homestead assured food and nutritional security for the farm family. The women had a major role in deciding the crops especially vegetables and conservation of indigenous seeds. Inclusion of more number of components thereby increasing the activities has added to manpower involvement and returns contributing to income of the family. The homestead models proposed for various zones of Kerala viz. southern, northern, central and problem zone and Andaman and Nicobar Islands, India formulated under the NATP project (2002) revealed additional net income in the range of ₹15000 to 37000 annually (NATP 2004). Mohan *et al*. (2007) stated that these intensively managed systems are often the only source of income for the household in Thrissur, Kerala, India.

Economic analysis of homesteads from two districts *viz.* Kannur and Kasargod of Kerala (Anilkumar *et al*., 2016) revealed the benefit cost ratio in the homesteads to range from 1.94 to 4.52 in Kannur and from 2.54 to 6.42 in Kasargod. Das and Das (2020) reported that homesteads continue to provide significant economic benefits to marginal farmers, apart from ecological benefits. Isaac *et al*. (2019) examined multiple products from a crop-livestock-poultry integrated homestead and assessed the percentage contribution to the annual net income of the family. Milk contributed maximum to the annual net income (40%) followed by coconut (27%), paddy (7%), tubers and spices (6% each), banana (5%), poultry and trees (4% each) and vegetables (1%).

The farmers in Barishal District, Bangladesh earned about USD 50 per year from homestead vegetable gardening which helped them to upsurge some sorts of financial safety and improve nutritional status of their families (Suza *et al*., 2021).

The financial security ensured from the diverse components adds to the resilience of the system and each

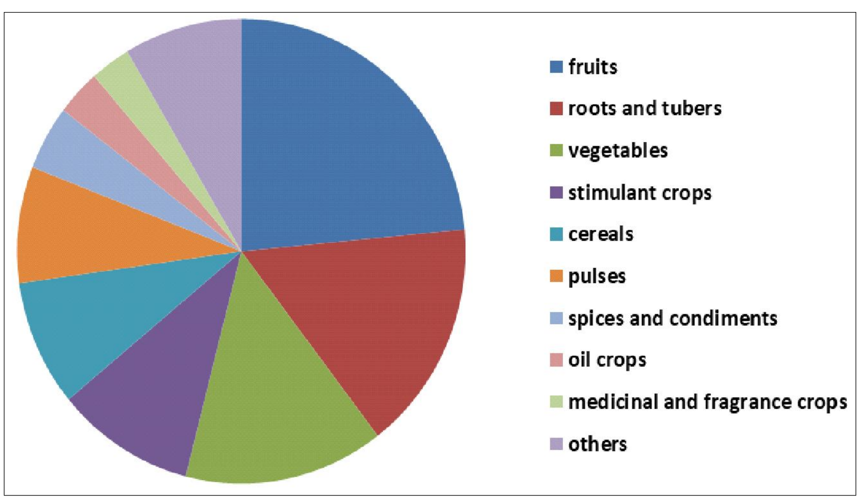

Fig 1: Species divesrity in Southern Ethiopia.

component functions as an insurance against vargeries of weather and losses. It can be concluded that over the years, homesteads have changed roles from subsistence farming to commercial farming. The metamorphosis was with the gain in popularity for cash/plantation crops.

Home garden flora was constantly dominated by exotic plant species but strongly connected to their surrounding ecosystems, being composed of at least 60% of plant species from their phyto-geographical districts and home garden plant species were mostly rare (Gbedomon *et al*., 2017).

CONCLUSION

Although homestead farming is practiced all over the world from time immemorial and several studies have been done on many aspects, elaboration of the resilience are less. The almost inherent resilient nature of homesteads makes the system unique and even an enigma. A better understanding of the resilient potential of the homesteads to varying environment is important to integrate the system in the agricultural production scenario of the nation so as to tide over the unpredictable events of climate change. Since there are calls from various countries recently for policies for homesteads, it should be treated as a global scale to maximize the ecological benefits. In the present changing scenario of the environment, efforts to strengthen homesteads for ensuring food security would also bring resilience to the agro ecosystem which will provide the best of two worlds.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Abebe, T., Wiersum, K.F., Bongers, F. (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of southern Ethiopia. Agroforestry Systems. 78: 309-322.

Abraham, J. (1997). Nutrient cycling and soil productivity studies of homestead agroforestry systems of Southern Kerala M.Sc. (Ag) Dissertation. Kerala Agricultural University, Thrissur.

Alam, M. and Furukawa, Y. (2010). Agroforestry Homegardens in Rural Landscapes of Bangladesh. In: Sustainable use of Biological Diversity in Socio-ecological Production Landscapes. [Belair, C, Ichikawa, K., Wong, B.Y.L. and Mulongoy, K.J. (eds)], Secretariat of the Convention on Biological Diversity, Montreal pp. 120-124.

Albrecht, A. and Kandji S.T. (2003). Carbon sequestration in tropical agroforestry systems. Agriculture Ecosystems and Environment. 99: 15-27.

Altieri, M.A. and Koohafkan, P. (2013). Strengthening Resilience of Farming Systems: A Key Prerequisite for Sustainable Agricultural Production. In: Wake up Before it is Too Late: Make Agriculture Truly Sustainable Now for Food Security in a Changing Climate, UNCTAD, TER13 Report, Geneva.

Anilkumar, A.S., Ambika, P., John, J. and Govindan, M. (2016). Krishi padashalayayi marunna mathruka veettuvalappukal. College of Agriculture, Kerala Agricultural University, Padannakkad.

Anilkumar, A.S., John, J. and Govindan, M. (2017). Vasantham viriyum veettuvalappukal. College of Agriculture, Kerala Agricultural University, Padannakkad.

Atangana, A., Khasa, D., Chang, S. and Degrande, A. (2014). Phytoremediation in Tropical Agroforestry. In: Tropical Agroforestry. [Atangana A, Khasa, D, Chang S, Degrande A (eds)], Springer, Dordrecht, pp. 343-351.

Bandyopadhyay, R., Ortega-Beltran, A., Akande, A., Mutegi, C., Atehnkeng, J., Kaptoge, L., Senghor, A.L., Adhikari, B.N. and Cotty, P.J. (2016). Biological control of aflatoxins in Africa: Current status and potential challenges in the face of climate change. World Mycotoxin Journal. 9(5): 771-789.

Beer, J., Muschler, R., Kass, D. and Somarriba, E. (1998). Shade management in coffee and cacao plantations. Agroforestry Systems. 38: 134-164.

Birhane, E., Ahmed, S., Hailemariam, M., Negash, M., Rannestad, M.M. and Norgrove, L. (2020). Carbon stock and woody species diversity in homegarden agroforestry along an elevation gradient in southern Ethiopia. Agroforestry Systems. 94: 1099-1110.

Birhane, E., Ahmed, S., Hailemariam, M., Negash, M., Rannestad, M.M. and Norgrove, L. (2020). Carbon stock and woody species diversity in homegarden agroforestry along an elevation gradient in southern Ethiopia. Agroforestry Systems. 94: 1099-1110.

Blanckaert, I., Swennen, R.L., Flores, M.P., López, R.R. and Saade, R.L. (2004). Floristic composition, plant uses and management practices in homegardens of San Rafael Coxcatlán, valley of Tehuacán-Cuicatlán, Mexico. Journal of Arid Environment. 57(2): 179-202.

Blanco-Canqui, H. and Lal, R. (2010). Soil Resilience and Conservation. In: Principles of Soil Conservation and Management. [Blanco, H., Lal, R. (eds)], Springer, Dordrecht. pp. 425-447.

Bullock, J.M, Dhanjal-Adams, K.L., Milne, A., Oliver, T.H., Todman, L.C., Whitmore, A.P. and Pywell, R.F. (2017). Resilience and food security: Rethinking an ecological concept. Journal of Ecology. 105(4): 880-884.

Cambridge University Press, (2008). Cambridge advanced learner's dictionary. Available: https://dictionary.cambridge.org.

Chandrashekara, U.M. and Baiju, E.C. (2010). Changing pattern of species composition and species utilization in homegardens of Kerala, India. Tropical Ecology. 51(2): 221-233.

Chandrashekara, U.M., Sreejith, K.A., Sandeep, S., Swamy, G.E.M.V.B., Sreekumar, V.B. and Amruth, M. (2018). Assessment of ecosystem services for conservation and management of sacred groves in Kerala part of Western Ghats. https://www.researchgate.net/publication/329238120_Assessment_ of_ecosystem_ services_for_ conservation_ and_management_of_ sacred_groves_ in_Kerala_ part_of_Western_ Ghats/link/5bfe4509a6fdcc35428cbcb7/download.

Chapin, F.S. III., Bergeron, Y., Fukuda, M., Johnstone, J.F., Juday, G., Zimov, S.A. (2004). Global change and the boreal forest: Thresholds, shifting states or gradual change? Ambio. 33: 361-365.

Chen. B. and Liang, L. (2020). Old-Growth trees in homesteads on the Ryukyu Archipelago, Japan: Uses, management and conservation. Small-scale Forestry. 19: 39-56.

Christanty, L. (1981). An ecosystem analysis of West Javanese homegardens. East West Center Environment and Policy Institute Working Paper, Honolulu.

Christanty, L., Abdoellah, O.S., Marten, G.G. and Iskandar, J. (1986). Traditional Agroforestry in West Java: The Pekarangan Homegardens and Kebun-talun Annual-perennial Rotation Cropping Systems. In: Traditional Agriculture in Southeast Asia: A Human Ecology Perspective. [Marten, G.G. (ed)], Boulder, Colorado, pp. 132-158.

Das, T. and Das A.K. (2020). Agrobiodiversity in northeast India: A Review of the Prospects of Agrobiodiversity Management in the Traditional Rice Fields and Homegardens of the Region. In: Socio-economic and Eco-biological Dimensions in Resource use and Conservation. [Roy, N., Roychoudhury, S., Nautiyal, S., Agarwal, S.K., Baksi, S. (eds)], Springer, Cham, pp. 117-134.

Das, T. and Das, A. (2005) Inventorying plant biodiversity in homegardens: A case study in Barak valley, Assam, North East India. Current Science. 89: 155-163.

de Freitas, A.V.L., Coelho, M.D.F.B., Biserra, Y., Pereira, E.C.D.F.N., Camili, E.C. and Spiller, C. (2020). Farmers homegardens in São João da Várzea, Rio Grande Do Norte. Brazilian Journal of Global Bioscience. 9(2): 6819-6841.

Elevitch, C.R. and Manner, H.I. (2006). *Artocarpus heterophyllus* (jackfruit). Species profiles for Pacific Island agroforestry. https://retirenicaragua.files.wordpress.com/2012/05/a-heterophyllus jackfruit1.pdf. Accessed 07 July 2020.

Engels, J. (2001). Home Gardens-a Genetic Resource Perspective. In: Proceedings of the Second International Home Garden Workshop. [Watson, J.W. and Eyzaguirre, P.B. (eds)], Bioversity International, Rome, pp. 3-9.

Gajaseni, J. and Gajaseni, N. (1999). Ecological rationalities of the traditional homegarden system in the Chao Phraya Basin, Thailand. Agroforestry Systems. 46(1): 3-23.

Gbedomon, R.C., Salako, V.K., Adomou, A.C. *et al.* (2017). Plants in traditional home gardens: Richness, composition, conservation and implications for native biodiversity in Benin. Biodiversity Conservation. 26: 3307-3327.

Gorman, C.F. (1971). The Hoabmhian and after: Subsistence patterns m south east asia during the late pleistocene and early recent periods. World Archaeology. 2(3): 300-320.

Harvey, M. (2006). Cultivating Resilience: The rehabilitation of Homestead Gar-dens in Post-tsunami Sri Lanka. In: Proceedings of the 3rd International I-rec Conference and Student Competition on Post-disaster Reconstruction. Florence, Italy.

Heal, O.W. anderson, J.M. and Swift, M.J. (1997). Plant Litter Quality and Decomposition: An Historical Overview. In: Driven by Nature: Plant Quality and Decomposition. [Cadish, G., Giller, K.E. (eds)], CAB International, Wallingford, pp 3-30.

Herrick, J.E. and Wander, M.M. (1998). Relationships Between Soil Organic Carbon and Soil Quality in Cropped and Rangeland Soils: The importance of Distribution, Composition and Soil Biological Activity. In: Soil Processes and the Carbon Cycle, [Lal, R., Kimble, J.M., Follett R.F. and Stewart, B.A. (eds)], CRC Press, Boca Raton pp. 405-426.

Huai, H. and Hamilton, A. (2009). Characteristics and functions of traditional homegardens: A review. Frontiers of Biology in China. 4(2): 151-157.

Isaac, S.R. (2001). Litter decomposition and nutrient dynamics of selected multipurpose trees in homesteads. PhD Dissertation. Kerala Agricultural University, Thrissur.

Isaac, S.R., Sheela, K.R., Podikunju, B., Anjaly, V. and Krishnapriya, S. (2019). Homestead farming research in Kerala. Kerala Agricultural University, Thrissur 104 p.

John, J. (2014). Homestead farming in Kerala: A multi-faceted land-use system. Rev Agrarian Stud. 4(1): 80-94.

Jose, D. and Shanmugaratnam, N. (1993). Traditional homegardens of Kerala: A sustainable human ecosystem. Agroforestry Systems. 24(2): 203-213.

Kala, C.P. (2010). Home gardens and management of key species in the Pachmarhi biosphere reserve of India. Journal of Biodiversity. 1(2): 111-117.

Karyono. (1990). Home Gardens in Java their Structure and Function. In: Tropical Home Gardens. [Landauer, K. and Brazil, M. (eds)], The United Nations University, Tokyo, pp. 138-146.

Kumar, B.M. (2006). Carbon Sequestration Potential of Tropical Homegardens. In: Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry. [Kumar, B.M. and Nair, P.K.R. (eds)], Springer, Dordrecht, pp. 185-204.

Kumar, B.M. (2015). Homegardens as Harbingers of Belowground Biodiversity in the Humid Tropics. In: Soil Biodiversity: Inventory, Functions andmanagemment. [Saxena, K.G. and Rao, K.S. (eds)], Bishen Singh Mahendra Pal Singh, Dehra Dun pp. 373-382.

Kumar, B.M. and Nair, P.K.R. (eds) (2006). Tropical homegardens: A time-tested example of sustainable agroforestry. Springer, Dordrecht.

Kumar. B.M. and Nair, P.K.R. (2004). The enigma of tropical homegardens. Agrofor Syst. 61: 135-152.

Kushwaha, H.L. (2019). Robotic and mechatronic application in agriculture. RASSA Journal of Science for Society. 1(3): 89-97.

Lin, B.B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. Bio Science. 61(3): 183-193.

Liu, Q., Peng, P.H., Wang, Y.K., Xu, P. and Guo, Y.M. (2019). Microclimate regulation efficiency of the rural homegarden agroforestry system in the western Sichuan plain, China. Journal of Mountain Science. 16(3): 516-528.

Magdoff, F. and Weil, R. (2004). Soil Organic Matter Management Strategies. In: Soil Organic Matter in Sustainable Agriculture. [Magdoff, F. and Weil, R. (eds)], CRC Press, Boca Raton, pp. 44-65.

Mohan, S., Nair, P.K.R. and Long, A.J. (2007). An assessment of ecological diversity in homegardens: A case study from Kerala State, India. Journal of Sustainable Agriculture. 29(4): 135-153.

Mohri, H., Lahoti, S., Saito, O., Mahalingam, A., Gunatilleke, N., Hitinayake, G., Takeuchi, K. and Herath, S. (2013). Assessment of ecosystem services in homegarden systems in Indonesia, Sri Lanka and Vietnam. Ecosystem Services. 5: 124-136.

Mukhopadhyay, D. (2009). Cultural values, indigenous knowledge for climate change adaptations in developing countries. In IOP Conference Series: Earth and Environmental Science (EES). https://iopscience.iop.org/article/10.1088/1755-1307/6/57/572006/pdf.

Nair, P.K.R., Buresh, R.J., Mugendi, D.N., Latt, C.R. (1999). Nutrient Cycling in Tropical Agroforesty Systems: Myths and Science. In: Agroforestry in Sustainable Agricultural Systems. [Buck, L.E., Lassoie, J.P. and Fernandes, E.C.M. (eds)], CRC Press, Boca Raton, pp. 1-31.

Nair P.K.R., Nair, V.D., Kumar B.M., Showalter, J.M. (2010) Carbon Sequestration in Agroforestry Systems. In: [Sparks, D. (ed)]. Advances in Agronomy. 108: 237-307.

NATP, (2004). Analysis and development of homestead farms of Kerala and Andaman group of islands-a farmer participatory approach. College of Agriculture, Padannakkad.

Nelson, D., Adger, W.N. and Brown, K. (2007). Adaptation to environmental change: Contributions of a resilience framework. Annual Review of Environment and Resources. 32: 395- 419.

Ninez, V. (1987). Household gardens: theoretical and policy considerations. Agric Syst. 23(3): 167-186.

Pinho, R.C., Alfaia, S.S., Miller, R.P., Uguen, K., Magalhaes, L.D., Ayres, M., Freitas, V. and Trancoso, R. (2010). Islands of fertility:soil improvement under indigenous homegardens in the savannas of Roraima, Brazil. Agroforestry Systems. 81(3): 235-247.

Puri, S. and Nair, P.K.R. (2004). Agroforestry research for development in India: 25 years of experiences of a national program. Agroforestry Systems. 61(1-3): 437-452.

Randhawa, M.S. (1980). The History of Agriculture in India vol 2 Eight to Eighteenth Century. Indian Council of Agricultural Research, New Delhi.

Rao, K.P.C., Verchot, L.V. and Laarman, J. (2007). Adaptation to climate change through sustainable management and development of agroforestry systems. Journal of SAT Agricultural Research. 4(1): 1-30.

Salim, M.V., Miller, R.P., Ticona-Benavente, C.A., van Leeuwen, J. and Alfaia, S.S. (2018). Soil fertility management in indigenous homegardens of central Amazonia, Brazil. Agroforestry Systems. 92(2): 463-472.

Schroeder, P. (1994). Carbon storage benefits of agroforestry systems. Agroforestry Systems. 27: 89-97.

Seneviratne, G., Kuruppuarachchi, K.A.J.M., Somaratne. S., Seneviratne, K.A.C.N. (2006). Nutrient cycling and safety-net mechanism in the tropical homegardens. International Journal of Agricultural Research. 1(2): 169-182. doi: 10.3923/ijar.2006.169.182.

Sindhu, S.S., Rakshiya, Y.S. and Sahu, G. (2009). Biological control of soilborne plant pathogens with rhizosphere bacteria. Pest Technology. 3: 10-21.

Soemarwoto, O. and Soemarwoto, I. (1984). The Javanese Rural Ecosystem. In: An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia. [Rambo, A.T., Sajise, P.E. (eds)], University of the Philippines, Los Banos, pp 25-87.

Suza, M.K., Hasan, S.S., Ghosh, M.K., Haque, M.E. and Turin, M.Z. (2021). Financial security of farmers through homestead vegetable production in Barishal District, Bangladesh. European Journal of Humanities and Social Sciences. 1(4): 65-71.

Swiderska, K., Reid, H., Song, Y., Li, J., Mutta, D., Ongogu, P., Mohamed, P., Oros, R. and Barriga, S. (2011). The role of traditional knowledge and crop varieties in adaptation to climate change and food security in SW China. Bolivian Andes and coastal Kenya. https://www.osti.gov/etdeweb/servlets/purl/22073504.

Tangjang, S. and Arunachalam, K. (2009). Microbial population dynamics of soil under traditional agroforestry systems in Northeast India. Research Journal of Soil Biology. 1(1): 1-7.

Thaman, R.R. (1985). Mixed Gardening in the Pacific Islands: Present Status and Future Prospects. In: Proceedings of First International Workshop on Tropical Homegardens, Bandung, pp 41-65.

Tolera, M., Asfaw, Z., Lemenih, M. and Karltun, E. (2008). Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. Agriculture Ecosystem and Environment. 128(1-2): 52-58.

Torquebiau, E. (1992). Are tropical agroforestry homegardens sustainable? Agriculture Ecosystems and Environment. 41: 189-207.

Upadhyaya, K., Sahoo, U.K., Vanlalhriatpuia, K. and Roy, S. (2012). Decomposition dynamics and nutrient release pattern from leaf litters of five commonly occurring homegarden tree species in Mizoram, India. Journal of Sustainable Forestry. 31(8): 711-726.

Wezel, A. and Bender, S. (2003). Plant species diversity of homegardens of Cuba and its significance for household food supply. Agroforestry Systems. 57(1): 39-49.

Zaldivar, M.E., Rocha, O.J., Castro, E. and Barrantes, R. (2002). Species diversity of edible plants grown in homegardens of Chibchan Amerindians from Costa Rica. Human Ecology. 30(3): 301-316.