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Agroforestry as An Adaptation to Climate Variability in Semi-arid Regions of Karnataka, India

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Abstract: The variability in climatic factors is expected to increase global temperature that could impact the growing pattern in agriculture system and increase drought scenarios. Agroforestry is an integral practice in traditional agriculture system, which has always proved to be less vulnerable to climate variability. The study was undertaken to assess the current scenario of agroforestry in semi-arid region of Karnataka wherein the relation between landholding and tree density in four districts was studied. A total of 32,683 individuals belonging to 26 tree species were recorded in 200 farmlands of which 22 were forestry tree species of 11,838 individuals with a density of 32 trees ha^{-1}. Apart from forestry species, the farmers cultivated 14,330 arecanut, 6458 coconut, 40 banana and 17 papaya trees respectively. The density of plantation trees was 57 ha^{-1} and the overall density of trees was 90 ha^{-1}. The results showed a significant correlation between tree density and landholding size indicating that number of trees in farmland increased as the landholding size increased. Such studies can help in developing recommendations in agroforestry practices in order to cope with agrarian crisis in arid and semi-arid regions. Information regarding tree species of area and their density will help to know the best preferred species by farmers and existing diversity of species based on which future agroforestry plantations can be planned.

Key words: Agroforestry, agrarian crisis, adaptations, agriculture, climate variability.

Climate variability is the principal source of imbalance in global food production in arid and semi-arid tropical countries of developing world (Sivakumar *et al*., 2005). The change in climatic factors will lead to increased global temperature which could impact the growing pattern in agriculture system and increase drought scenario (Quandt *et al*., 2017). Adaptation plays a major role in any future climate change regime and it has attracted increased attention in the recent past due to the impacts of climate change apparent around the world (UNFCCC, 2007; IPCC, 2014).

Agroforestry has traditionally being practiced in India as a way of life and livelihood since ancient time (Inder *et al*., 2018). Its practice is an excellent and feasible model in promoting mitigation and adaptation strategy to combat climate change (Murthy *et al*., 2013; Verchot *et al*., 2007; Bentrup *et al*., 2018) as it reduces vulnerability to climate change (Rijal, 2019). Although agroforestry practices may not be the one stop solution to climate change adaptation, it has a great potential to help farmers improve their well-being and maintain environmental sustainability (Thorlakson and Neufeldt, 2012). Agroforestry, especially those utilizing leguminous trees, also improves soil fertility, due to improvement in soil organic matter, biological nitrogen fixation, recycling of nutrients (Misra, 2011) and at many occasions ground water recharge (Mbow *et al*., 2014). It also provides fodder, timber and fuelwood besides environmental services because of checking of soil loss due to windbreaks, carbon sequestration and biodiversity (FAO, 2005). It also has the potential to improve the livelihood through stable income and diversification of land use (Smith, 2010).

Study on agroforestry contributed to sustainable policy options that promote short and medium term economic solutions while reducing vulnerability (Lasco *et al*., 2014). The present study was thus carried out to understand tree density and their end uses so as to understand the adaptive capacity of farmers in south interior semi-arid region of Karnataka.

Study Area

The study was carried out in four south interior districts of Karnataka viz., Chikballapur, Chitradurga, Kolar and Tumkur (Fig. 1). These

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areas are similar in geographical features and climatic conditions with no perennial water sources for agriculture. Crops such as pulses, groundnut, sunflower, coconut, arecanut, and paddy were predominant in Tumkur and Chitradurga districts where as Kolar and Chikballapur farmers were growing horticulture, floriculture, sericulture and vegetable crops.

Chikballapur district comes under eastern dry agro-climatic zone (GoK, 2019) characterized by semi-arid and typical monsoon tropical weather with hot summers and mild winters. The average rainfall in the district is 756 mm (CGWB, 2012a).

Chitradurga district comes under central, northern dry and southern transition agro-climatic zones of Karnataka. The climate of the district is characterized by semi-arid climate and typical tropical weather with hot summers and mild winters. It receives low to moderate rainfall and is one of the drought-prone districts in the state, the average rainfall in the district ranges from 457 mm in Challakere and 668 mm in Holalkere taluks (CGWB, 2017).

Kolar district comes under eastern dry agro-climatic zone (GoK, 2019), it is characterized by a semi-arid climate and typical monsoon tropical weather with hot summers and mild winters. The average rainfall in the district is 748 mm (CGWB, 2012b).

Tumkur district comes under central, southern dry agro-climatic zones (GoK, 2019), it is characterized by a semi-arid climate and typical tropical weather free from extreme conditions. The average rainfall in the district is 770 mm (CGWB, 2012c).

Methods

A mixed approach methodology (combination of quantitative and qualitative methods), along with tools from both social and environmental sciences were used for the study. Tools such as Participatory Rural Appraisal (PRA) and Focus Group Discussions (FGD) (Uddin and Anjuman, 2013) were adopted to understand the historical agriculture practice in the region. Qualitative and quantitative techniques were used to understand socio economic background of farmers and help in understanding their potential to adapt to climate change (Place *et al*., 2007).

Agricultural fields of the selected farmers (n=200), were visited and trees cultivated were identified and recorded. Species were identified using monographs and field guides (Bekele, 2007; Endale *et al*., 2016; Saldanha, 1984; Kavitha *et al*., 2012). Tree species with girth at breast height (gbh) of ≥15 cm were recorded. As the farmland sizes were small and trees were found in clusters, it was possible to enumerate all the trees present instead of adopting sampling approaches (Chaturvedi, 1990; Prasad *et al*., 2001). The end use of each species was recorded during farmlands survey and also through secondary literature.

Results and Discussion

Overview of the respondents

A total of 200 farmers were interviewed out of which 27% were from Chikballapur, 20% from

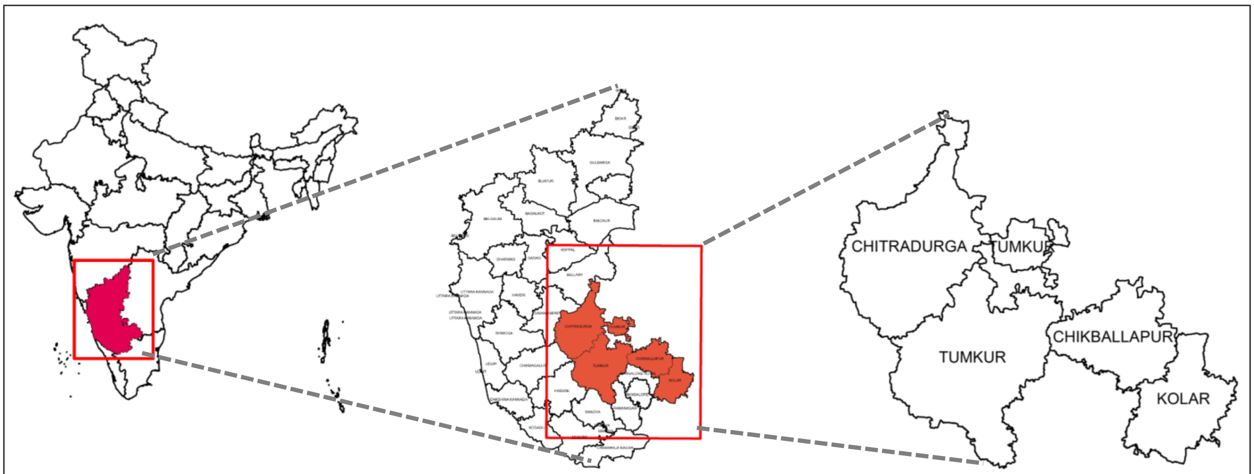

Fig. 1. Study area districts in Karnataka.

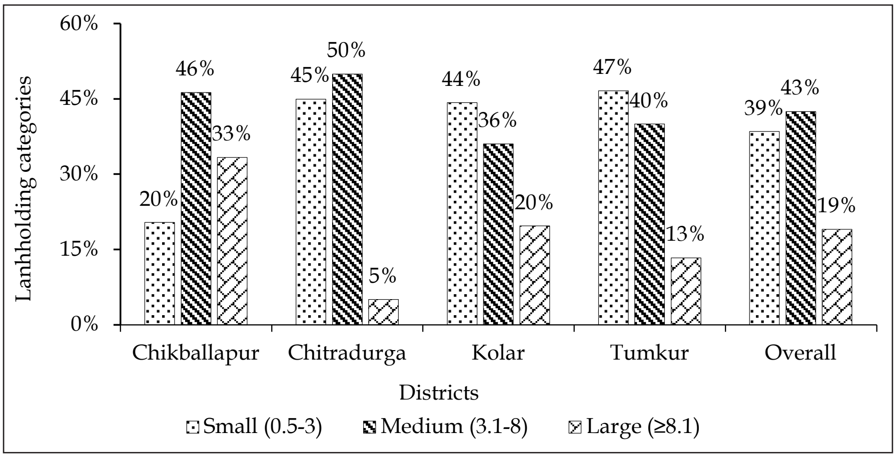

Fig. 2. Landholding status in four semi-arid districts of Karnataka.

Chitradurga, 30% from Kolar and 23% from Tumkur districts, respectively. The education status of the respondents revealed that 63% are educated and remaining 37% are uneducated. Among the educated 41% studied high school, 41% primary education, 5% graduation, 2% have undergone technical education and 1% have completed post-graduation.

The study also aimed at recording the nature of tree species across districts where the criteria for choice and end use of each species was recorded. The trees were grouped into three categories based on occurrence of trees on different landholding size (acre) viz., small (0.5-3), medium (3.1-8) and large (≥8.1) to examine the correlation between landholding size and agroforestry (Ravindranath and Somasekhar, 1995; Prasad *et al*., 2001).

The majority of respondents belonged to medium and small landholding size, who are highly vulnerable to climate change as the marginal and small farmers lack in capital. Landholding also influences the coping capacity as they do not have diverse source of agricultural income. A total of 43% respondent belonged to medium, 39% small and only 19% fell under large landholding category (Fig. 2). In Chitradurga district, 95% of the farmers fell under medium and small category, Chikballapur district had 33% large landholding farmers (maximum among four districts), whereas Tumkur district had highest small landholding farmers (47%) and Kolar district had 44% small, 36% medium and 20% large landholding farmers.

Agroforestry practice

Overall 67% of the respondents practiced agroforestry. Kolar was highest with 85% respondents practicing agroforestry followed by Chikballapur with 70% (Fig. 3), this can be attributed to the fact that many farmers are growing mango. Tumkur recorded 62% practising agroforestry. Chitradurga recorded 38% which is the lowest and this may be due to drought situation and significant number of farmers having small landholdings with

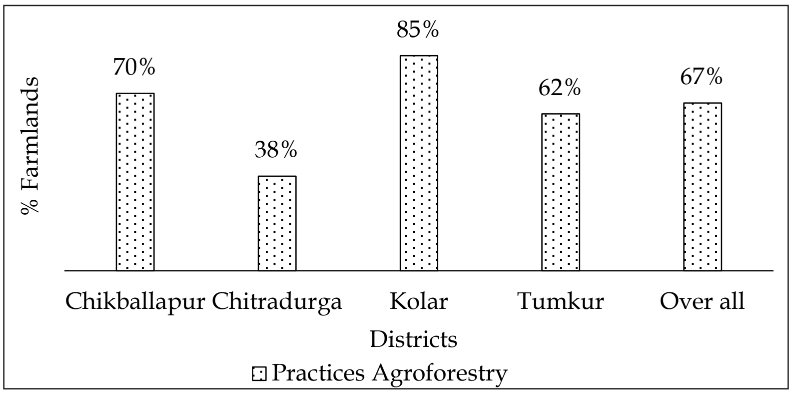

Fig. 3. Agroforestry practice in four semi-arid districts of Karnataka.

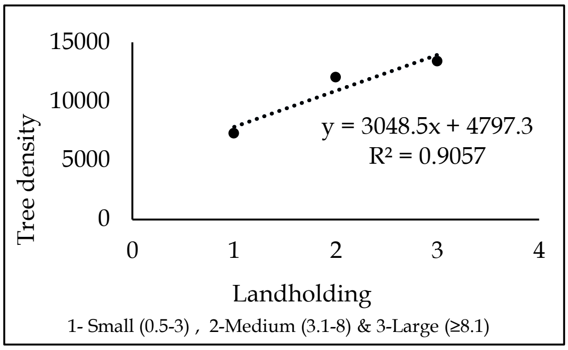

Fig. 4. Correlation between tree density and landholding in four semi-arid districts of Karnataka (n=200).

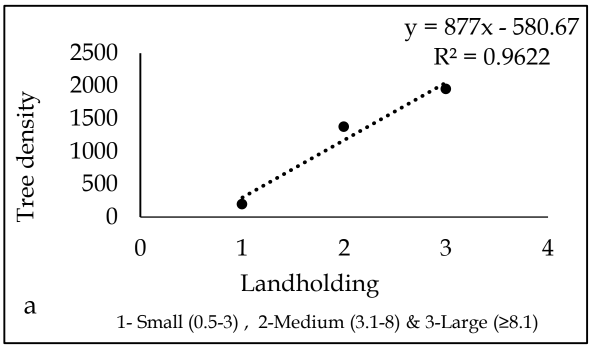

Fig. 4a. Correlation between tree density and landholding in Chikballapur (n=54).

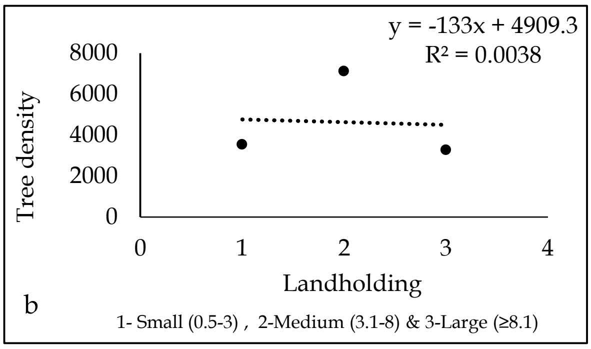

Fig. 4b. Correlation between tree density and landholding in Chitradurga (n=40).

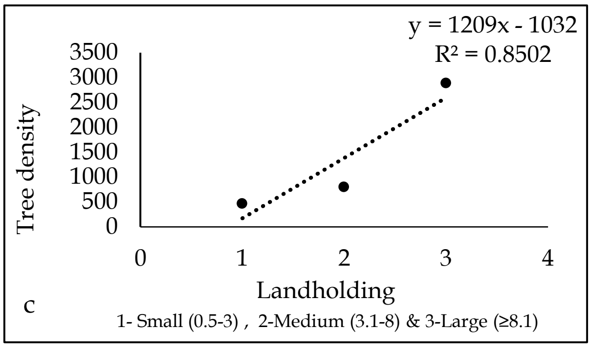

Fig. 4c. Correlation between tree density and landholding in Kolar (n=60).

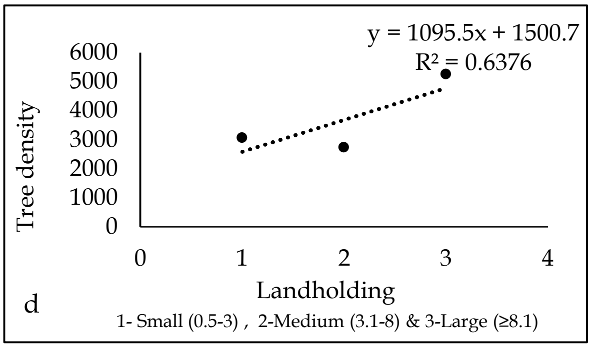

Fig. 4d. Correlation between tree density and landholding in Tumkur (n=46).

less proportion of farmers having large landholdings (Fig. 2).

Landholding and tree density

An attempt has been made to understand the relation between landholding and tree density in the four districts. The overall results revealed that there was a significant relationship between tree density and landholding size (Fig. 4) indicating an increase in the number of trees in farmland as the landholding size increased. Similar findings have also been recorded in the semi-arid region of Ethiopia with significant correlation between landholding size and density of trees (Endale *et al.*, 2016). Among the four districts studied, three districts viz., Chikballapur (Fig. 4a), Kolar (Fig. 4c) and Tumkur (Fig. 4d) showed positive relationship between tree density and landholding size. But there was no relationship between tree density and landholding size (Fig. 4b) in Chitradurga and it may be attributed to the fact that 50% of the farmers in the district belonged to small landholding categories, which followed rainfed

Table 1. Tree population in four semi-arid districts of Karnataka

Species	No. of individuals
Azadirachta indica A. Juss.	1759
Grevillea robusta A. Cunn. ex R. Br.	643
Tamarindus indica L.	705
Mangifera indica L.	1011
Moringa oleifera Lam.	11
Artocarpus heterophyllus Lam.	112
Ficus religiosa L.	11
Syzygium cumini var. cumini	59
Eucalyptus globulus Labill.	397
Ficus benghalensis L. var. krishnae (C. DC) Corner	1
Aegle marmelos (L.) Correa	5
Tectona grandis L. f.	1037
Cinnamomum camphora (L.) J. Presl	4
Pongamia pinnata (L.) Pierre	723
Santalum album L.	850
Anacardium occidentale L.	250
Murraya koenigii (L.) Spreng.	1
Melia dubia Cav	3763
Manilkara zapota (L.) P. Royen	55
Citrus limon (L.) Burm f.	222
Acacia auriculiformis A. Cunn. ex Benth.	18
Psidium guajava	201
Sub-total	11838
Plantation	
Areca catechu L.	14330
Carica papaya L.	17
Cocos nucifera L.	6458
Musa paradisiaca L.	40
Sub-total	20845
Grand Total	32683

cropping of pulses, cereals and groundnut. However, the medium landholding farmers of the district with irrigation facilities grew *Melia dubia* as tree crop plantation.

Density and diversity

A total of 32,683 individuals belonging to 26 tree species from 200 farmlands were recorded in the four semi-arid districts of Karnataka (Table 1). Out of the 26 tree species recorded, 22 belonged to forestry species with 11,838 individuals with a tree density of 32 trees ha^{-1} and rest were plantation trees such as Arecanut (14,330), Coconut (6458), Banana (40) and Papaya (17). The density of plantation trees was 57 ha^{-1} and the overall density of trees in the study was 90 ha^{-1}.

Among the end use classification (Table 2), 32% of tree species were fruit yielding followed by 28% timber yielding, 9% timber+fruit, 4% timber+fruit+leaves, 14% fruit+byproducts, 5% seed + manure and timber + leaves, timber + manure 4% each, respectively. The trend indicates that farmers were growing horticultural fruit yielding trees to provide them immediate economic security so as to reduce vulnerability and overcome adverse effects of climate variability in the region. Trees classified based on end use and analysis in a village ecosystem in Western Ghats of Karnataka indicated fruit and vegetable yielding species such as *Mangifera indica*, *Citrus* spp., *Musa* spp., etc., as dominant (30%) species followed by fuelwood and foliage species (Shasthri *et al.*, 2002).

Agroforestry as an adaptation

The study revealed that majority (67%) of the farmers are dependent on trees in the farmland

Table 2. List of tree species based on end use across four districts in study area

End usage	No. of individuals	Examples
Fruit	1744	*Mangifera indica, Manilkara zapota, Psidium guajava, Citrus limon*
Timber	2666	*Tectona grandis, Acacia auriculiformis, Grevillea robusta, Santalum album*
Fruit + timber	171	*Artocarpus heterophyllus, Syzygium cumini*
Timber + fruit + leaves	1759	*Azadirachta indica, Ficus* sp.
Fruit + byproducts	705	*Anacardium occidentale, Tamarindus indica*
Timber + leaves	397	*Eucalyptus globulus, Murraya koenigii*
Timber + manure	3673	*Melia dubia, Grevillea robusta*
Seed + manure	723	*Pongamia pinnata, Anacardium* sp.
Total	11838	-

for one or the other reason. Tree based faming is one of the integrated farming approaches that support the farmer to sustain agrarian crisis. Tree crops require supplemental irrigation and maintenance only for initial stage of their growth up to 2-3 years. Semi-arid tree species such as *Azadirachta indica* can also regenerate naturally and grow without any support; it is also a good source of fodder for goat, sheep and yields good quality timber.

Tamarindus indica is one of the important tree crops predominantly grown in Chitradurga and Tumkur districts. Apart from being an important tree crops, its byproducts such as coir, shells and seeds are also used as raw materials by many agro based industries. The byproducts can be used as mulching material in farms as it enriches the soil and prevents evaporation of water. Timber yielding crops such as *Melia dubia* is cultivated by farmers enmass, with initial supplemental irrigation and minimal maintenance, the trees attains harvestable maturity by 5-6 years; it also provides green manure and green fodder for cattle. Horticulture crops such as Mango, Guava, Sapota are primarily grown on commercial scale in Kolar and Chikballapur districts. Intercropping of food grains and pulses can be done along with horticulture trees, which enables farmers to also follow an integrated soil nutrient management practice. The tree crops apart from providing manure also provide an optimum level of shade for floriculture. Deep-rooted trees effectively utilize the available nutrients from the deeper strata of the soil. Intercrops provide periodic income to the farmers, whereas horticulture crops yield annually. The residues from intercrops act as green manure for the horticulture crops. Trees in dryland are often planted on field bunds and borders which act as live fence and windbreaks.

It can thus be concluded that agroforestry practice supports farmers to sustain drought years by growing horticulture crops with 67% of farmers in the study area depending on trees and horticulture crops for alternate source of income. Agriculture productivity in terms of economic output is higher in the alley cropping system when compared to monocrop practice (Xu *et al.,* 2019). Tree crops helps in soil fertility enrichment, ground water recharge, carbon sequestration and provide habitat for wildlife. Multi-storied farming is a characteristic of regenerative agroforestry that resulted from incorporating multiple species. It has a higher capacity to cut-off the sunlight than single-layered canopies resulting in reduced evaporation losses from the soil and also creates a microclimate suitable for specific crops. Similar to different strata of canopies above ground, the root system has different strata below ground, which enables effective utilization of available nutrients in the soil (Goudriaan, 2016; Lovell *et al.*, 2018; Elevitch *et al*., 2018).

Conclusion

Agroforestry as an integral practice in traditional agriculture system has always proved to be less vulnerable to climate variability and the adverse impacts of monsoon failures and shifting rainfall patterns. For a sustainable agriculture system in semi-arid region key components to keep agriculture system in balance are tree, livestock, healthy soil and skilled manpower. Besides providing livelihood to farmers, trees help in improving biodiversity, soil nutrients, moisture and ground water recharge.

Agroforestry system or tree-based farming in the study area has proved to be an effective and feasible adaptation. This method does not demand high capital investment; rather it transforms into productive and profitable farming while meeting the goal of sustainability. Hence, efforts have to be made to encourage farmers to take up tree-based farming through possibily convergence of different Central and State government schemes such as "Krishi Aranya Protsaha Yojane" that provides the monetary aid to raise the saplings in farmland with additional incentives in semi-arid regions. This study can also further help in deriving recommendations with climate resilient models, promoting sustainable agriculture and implementing land use policy in semi-arid regions of Karnataka.

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