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Development of adoption index: A proxy measure for assessing the adoption rate of agroforestry practices in Indian context

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Abstract
Adoption index for understanding the acceptance of different agroforesty systems has been discussed in the present paper, keeping in view the pros and cons of the previous indices presented by different workers. Our model considers the different factors like agroforestry systems, components of the systems, temporal aspects and the purpose of the agroforestry system for the estimation of adoption rate of different agroforestry models. This adoption Index will give an absolute measurement of adoption rate and the definite position to a farmer on the continuum path of adoption, which can reflect the adoption level of individual farmers and could be appropriate rather than binominal models (adopters versus non-adopters) as this would minimize the definitional problem regarding the exact delineation between 'non-adopters', 'testers' and 'adopters' and 'pseudo adopters.

Keywords: Adoption index, agroforestry, integrated farming, technology transfer failures

Introduction

There is an urgent need to develop strategies that will improve agricultural productivity, while maintaining environmental integrity in preview of sustainable intensification of agriculture. Despite the modest success in reducing food insecurity, there are still around 795 million people worldwide who remain undernourished. In many of these impoverished communities, agriculture still remains as the most important sectors in driving economic growth and reducing poverty. In India, agriculture is mainly practiced by smallholder farmers, who occupy the large share of agricultural land and produce major share of crop and livestock products. Most of the farmers occupy less than one hectare of land, which too is not at one place but distributed at different places posing much difficulty in practicing mechanized agriculture. Prevalence of small-scale farming activities in the country challenges the ever-growing demand for agricultural products, which is further aggravated by low soil fertility, degrading soil and environment health and changing climate. As a result of these challenges, smallholder agriculture remains at low productivity and this has led to high incidence of poverty among rural smallholder farmers (Ajayi, 2007; Ajayi *et al*. 2007) [3, 4]. In the face of growing population, sustainable intensification through agroforestry, which involves diversified and high productivity per unit agricultural land, is widely viewed as an important strategy to respond to the challenges of low yields, environmental degradation and adaptation to climate change (Antle and Diagana, 2003) [5]. Agroforestry is the practice and science of the interface and interactions between agriculture and forestry, involving farmers, livestock, trees and forests at multiple scales. Spatial and temporal interactions between trees and other components of agriculture may be important at a range of scales: in fields (where trees and crops are grown together), on farms (where trees may provide fodder for livestock, fuel, food, shelter or income from products including timber) and landscapes (where agricultural and forest land uses combine in determining the provision of ecosystem services) (Van Noordwijk *et al*., 2016) [16]. Agroforestry systems range from subsistence livestock and pastoral systems to home gardens, alley intercropping and biomass plantations which all have different context-specific biophysical conditions and socio-ecological characteristics (Zomer *et al*., 2014) [17]. Agroforestry is widely regarded as a potential strategy that will help farmers in climate change mitigation and adaptation, improve low agricultural productivity and contribute to household food security (Mbow *et al*., 2014) [10].

Improved food productivity and crop diversification represent a buffer mechanism against harvest failure due to climate and other environmental hazards. Using data from long term field trials, crop yields under agroforestry systems are more stable over time as compared to crop yields from non-agroforestry fields (Sileshi *et al*. 2012) [13]. This is due to increased soil water in fields under agroforestry (Chirwa *et al*., 2007) [6], reduced evaporation losses and protection of crops from excessive heat on fields that have increased tree cover. Despite all its potential, the level of diffusion of agro-forestry technologies has generally lagged behind thereby reducing their potential impacts (Mercer 2004) [11]. However, unless farmers widely adopt these technologies as part of their farming system, the potential benefits of agroforestry on livelihoods and the environment will not be realized. This scenario activated many scientists and social scientist to carry out adoption studies. A myriad of studies have been performed to assess the adopting rate of agroforestry practices in different parts of world. But the method employed by most of the workers didn't give clear picture but an overall approximate idea of adoption rate. To get a clear cut objective idea of agroforestry adoption rate, development and derivation of adoption index in Indian context has been suggested in this paper

Shortfalls in the methods adopted by earlier workers

Most of the workers carried out adoption rate studies consider it bivariate means either adopters or non-adopters. Dividing the farmers into two categories adopters and non-adopters will not do justice to adoption studies as adoption is a temporal process and farmers may be at different stages of adoption. The farmer who is practicing only one agroforestry practice has been considered to be adopter and placed in the same category of the other farmer who has been practicing more than one agroforestry practices. Secondly the adoption rate has been assessed at a single point of time, while agroforestry is a continuous process. The literature on agroforestry adoption mostly discusses early adopters and the use of the innovation at a specific point in time (Kiptot *et al*., 2007). The farmer who has been practicing agroforestry for one year cannot be considered similar to the farmer who has been practicing the agroforestry for five or more years. Few workers recently introduced a new class in between adopter and non-adopters i.e. testers. Testers are those who are in initial phase of practicing agroforestry. But it was not specified that what is the time lag between adopter and tester, how many years after practicing agroforestry, a tester will become adopter. Some workers like Kiptot *et al*. (2007) specified a new class i.e. pseudo-adopter (the farmers who has taken up the technology not for its own benefits but the associated benefits like such as obtaining credit, prestige or cash from selling seed). Although categorizing the farmers to different categories improved the adoption studies but still many lacunas were there. Considering agroforestry a dynamic process, there is need to develop an adoption index that can reflect the adoption level of individual farmers, would be more appropriate rather than binomial models (adopters versus non-adopters) as this would minimize the definitional problem regarding the exact delineation between 'non-adopters', 'testers' and 'adopters' and 'pseudo-adopters. Recently an adoption index has been developed in Nepalese context considering adoption an continuous process and farmers at different stages of continuum path. But it is purely based on number of components taken up in the agroforestry practices. Secondly, this index included diversity of agriculture crops and livestock whereas agroforestry is all about spatial and temporal arrangement of different components (agriculture, horticulture, forestry, livestock) on the same piece of land. An agroforestry system with one agriculture crop will be called as agri-silviculture system and with two or more than two agriculture crops will also be called as agri-silviculture system. Same is the case with the inclusion of livestock in an agroforestry system. Diversity within each component did not really matter in assessment of adoption. Thirdly, there is no mention of number of years the farmer is practicing the agroforestry. Lastly, the purpose of agroforestry has also not being taken care of. Some farmers fulfill their basic requirements; other farmers took the well-developed scientific agroforestry models to generate additional revenue or fulfilling the purpose of soil enrichment or conservation. The purpose of agroforestry should also be included in the adoption index derivation as purpose shows farmer's scientific wisdom about agroforestry adoption. Therefore, an adoption index has been developed with modifications in Indian context.

Derivation of index value (IV)

Here the dependent variable is Adoption Rate. There are different agroforestry systems prevalent in India namely agri-silviculture, agri-horticulture, silvi-pasture, border planting, block planting, home-gardens etc. Farmer may be practicing one or more than one agroforestry systems.

$$IVS = \overline{} \sum_{s=1}^{n} s/n$$

Where, IVP is the Index value for agroforestry systems, n is the total number of systems which may ever be prevalent in the studied area, s is the number of systems adopted by individual farmer.

$$IVC = \overline{} \sum_{c=1}^{n} c/n$$

Where, IVC is the Index value for agroforestry components, n is the total number of components and c is the number of components in the farmer's field. There are four components in agroforestry agriculture, horticulture, livestock and forestry. A farmer will be assigned the score according to the number of components in their field.

$$IVT = \overline{} \sum_{t=1}^{n} t/n$$

Where, IVT is the Index value for time, the third component is time. Time has been divided into five classes. Total number of classes are 5 so n is 5. If a farmer is practicing the agroforestry 0-10 years, then t will be one. In this way scores will be assigned according to number of years a farmer has been practicing agroforestry.

Table 1: In this way scores will be assigned according to number of years a farmer has been practicing agroforestry

Years	Score (n)
0-10	1
10-20	2
20-30	3
30-40	4
More than 40 years	5

$$IVP=\sum_{p=1}^{n} a/n$$

Where, IVP is index value for the purpose of undertaking agroforestry, n is the total number of purposes with which the farmers of a particular area have undertaken agroforestry and p is the number of purposes for which an individual farmer has been practicing the agroforestry

$$AI=\sum (IVS+IVC+IVT+IVP)/4$$

Where, AI is the adoption index. This adoption index (AI) was used as a dependent variable as a proxy measure of the adoption of agroforestry practices.

Discussion

Agroforestry embraces an agro-ecological approach, emphasizing multi-functionality involving complex systems at different scales, i.e., integrating trees and shrubs (for fertilizer, fodder, wood or fruit), palms and bamboo with annual crops and livestock, thus creating a new input-output system (Mercer, 2004; van Noordwijk *et al*., 2014) [11, 15]. Due to this multi-faceted, multi-component and the multiple product nature, adoption of agroforestry practices tends to be more complex and knowledge intensive, especially the factors that contribute to adoption constraints. Moreover, the realization of the full adoption benefits of agroforestry are only in the medium-long run term (usually 3-6 years), as compared to a few months it takes as in case of improved varieties or organic fertilizer (Mercer, 2004) [11]. Adoption of complex management practices is a gradual and incremental process where farmers experiment on small areas first and only expand when they are convinced of the benefits (Giller *et al*. 2009) [8].

However, measuring the adoption level at household level is problematic in the agroforestry practices. There have been a plethora of studies with regards to adoption (Adesina and Chianu 2002; Dhakal, 2015) [1, 7]. Most of these studies have used dichotomous and multiple choice (Logit, probit or tobit) regression models to explain how various characteristics of farmers, farm, market incentives, and development projects influence the adoption decision and also concentrated on individual technologies while analyzing the factors affecting farmers' adoption decision.

Adoption of agroforestry has traditionally been operationalized in two ways within existing empirical studies. First, as a binary, dichotomous choice, taking the value of 1 if the farmer uses the practice after being exposed and 0, if otherwise (Neupane *et al.* 2002; Thangata and Alavalapati, 2003) [12, 14]. This definition has received much criticism since it considers the adoption decision for only one period which fails to capture the temporal and spatial dynamics of adoption process. Secondly, as a continuous but static measure of the occurrence of tree cover of greater than 10% on agricultural lands using remote sensing techniques (Zomer *et al*., 2014) [17]. Ajayi *et al*. (2003) [2] regarded the uptake of agro-forestry technologies as a continuum and asserted farmers can be assigned positions in the continuum based on the extent of uptake of the different components of the technology.

Farmers' adoption of such technologies must be seen as a continuum. When trying to understand adoption decisions, researchers should make sure that they spend enough time to evaluate the entire sequence of adoption processes from initial adoption to technology modification/adaptation. Some farmers may be adopting only one agroforestry practice and may have two components while other farmer may practicing the agroforestry for quite some time and may be having two or more than two agroforestry systems with all four components. Keeping the farmers only in two categories of adopters and non-adopters will not do justice to the adoption rate studies. Therefore, this adoption index includes number of agroforestry practices undertaken, number of components in the farmer field, time (for how long the farmer is practicing the agroforestry) and the purpose. This adoption index will give a an absolute measurement of adoption rate. This adoption index will give definite position to the farmer on the continuum path of adoption. It will help in differentiating the farmer who has taken the agroforestry on experimental purposes to the one who is a real adopter and practicing agroforestry for quite some time. Purpose of taking up an agroforestry system has also been included in the calculation of adoption index because it shows the scientific understanding of farmer about agro forestry. It has been mentioned by few earlier workers that sometime farmers participate or take up an agroforestry system under an agroforestry program in order to sell seed to projects, obtain credit from projects promoting the practice, participate in seminars and gain prestige. So such a farmer will be clearly be differentiated by including purpose in the derivation of adoption index.

Conclusion

Despite some impressive scientific and technological advances over the last three decades, agroforestry rural development projects have experienced uneven success rates in many parts of the world due to inadequate adoption rates and/or abandonment soon after adoption. In the context of climate change where agroforestry is considered as a climate smart farming, it is of utmost importance to study what factors lead farmers towards adopting such promising land management practice so that it can be unscaled in other parts. To classify farmers into two groups, adopters and non-adopters, is often an over-simplification. In fact, we can see an adoption continuum path, with farmers falling in different categories along the path, depending on how they use the technologies. Farmers have been classified into four groups; non-adopters, adopters, testers/experimenters and pseudo-adopters. This classifying of farmers certainly helps minimize variations within the group and hence gets better results than binary choice models do. However, this delineation also fails to differentiate between single technology adopters and multiple technology adopters as discussed earlier categories. Adoption is a continuum where individual farmers are conceptualized to occupy positions along a continuum of adoption path depending on the extent to which they have taken up various components of the technology. Considering the complexity of the agroforestry adoption process, derivation of adoption index taking care of components, time, number of systems undertaken and purpose will give more clear idea about the adoption rate and process of adoption in a locality. Therefore, an adoption index that can reflect the adoption level of individual farmers could be appropriate rather than binomial models (adopters versus non-adopters) as this would minimize the definitional problem regarding the exact delineation beteen 'non-adopters', 'testers' and 'adopters' and 'pseudoadopters.

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