National Agroforestry Policy 2014 and the need for area estimation under agroforestry

India faces a critical imbalance in its natural resource base with about 18% human and 15% of livestock population of the world being supported only by 2.4% of geographical area, 1.5% of forest and pasture lands and 4.2% of water resources. Besides, about 60% of the cropped area in the country is rainfed, where the yield levels are highly prone to a variety of risks. For such areas, diversification of land-use systems with agroforestry is a necessary strategy for providing a variety of products for meeting the requirements of the people, insurance against risks caused by weather aberrations, controlling erosion hazards and ensuring sustainable production on a long-term basis.

Agroforestry plays a vital role in the Indian economy by way of tangible and intangible benefits. It has helped in rehabilitation of degraded lands on one hand and has increased farm productivity on the other. At present agroforestry meets almost half of the demand of fuel wood, two thirds of the small timber, 70–80% wood for plywood, 60% of raw material for paper pulp and 9–11% of the green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fibre, medicine, etc.[1]. Industries have taken up poplar, *Eucalyptus*, bamboo, *Acacia*, *Casuarina*, *Ailanthus* and teak for commercial agroforestry due to their great market potential. Genetically improved clonal planting stock of eucalypts, poplars and acacias has transformed the productivity and profitability of plantations. Average yields from such clonal plantations are 20–25 times higher compared to the average productivity of forests in India. In fact, agroforestry has high potential for simultaneously satisfying three important objectives, viz. protecting and stabilizing the ecosystems; producing a high level of output of economic goods and improving income and basic materials for the rural population. Besides, agroforestry is capable of conserving natural resources under different agro-climatic regions and is the only option to increase the forest/tree cover from the present less than 25% to 33% in the country. Agroforestry is also playing the greatest role in maintaining the resource base and increasing overall productivity in the rainfed areas in general and the arid and semi-arid regions in particular.

Agroforestry with so much contribution and potential has not gained the desired importance as a resource developmental tool due to its dependency on multi-institutions and multi-disciplinary approach. At the highest level, while the Ministry of Agriculture, Government of India has the mandate for agroforestry research, agriculture is a state subject and forestry is in the concurrent list and there are no extension services dedicated for its promotion. Besides, restrictions imposed by the State Government (as per Section-41 of India Forest Act) on felling and transportation of trees grown even on farmland, legal requirements for obtaining permits for felling and transportation, lack of institutional finances, absence of adequate infrastructure for marketing wood produce and lack of market information are some of the few hurdles which discourage the farmers from undertaking tree planting on farmland. Also, research results of agroforestry available in the public and private domain do not reach the farmers due to lack of a dedicated extension system. There is a serious lack of institutional mechanisms to promote agroforestry at all levels.

To overcome these hurdles, India has announced the landmark National Agroforestry Policy 2014 (http://www.indiaenvironmentportal.org.in/content/389156/national-agroforestry-policy-2014/) that will mainstream the growing of trees on farms to meet a wide range of developmental and environmental goals. For planning and implementation, the Policy has recommended to develop a sound database and information system on agroforestry. However, at present unlike forest cover and area under crops, exact estimates for area under agroforestry are not available. The major problem in estimating the same lies in the different modes in which it occurs. The current area under agroforestry in India is estimated as 25.32 m ha, or 8.2% of the total geographical area of the country[2]. This includes 20 m ha in cultivated lands and 5.32 m ha in other areas. However, the estimates are not based on revenue records or actual measurement.

Dhyani *et al.*[2] had pointed out that the assessment of FSI[3] for forest cover (69.20 m ha) and trees outside forests (9.08 m ha) in fact are overestimates, as they include a large area of agroforestry, mainly agrisilviculture, block plantations, orchards (agri-/silvi-pasture) on crop lands, homestead, scattered trees on farms and so on. The actual area under forest in both the classes will be less than these estimates. This has also been questioned by Ravindranath *et al.*[4] recently, when they mentioned that the area under forests in India is being overestimated as it includes several plantation/orchard vegetation categories such as coffee, coconut, mango, cashew nut and apple.

For agroforestry purpose, forest cover assessment of the country through conventional methods before the use of satellite data may give some indication about how much area of agroforestry is likely to be included in these estimates. The forest cover estimates[5] varied from 1987 to 1999 between 63.33 m ha (1997) and 64.08 m ha (1987), and the figures of 67.55 m ha (2001) and 69.20 m ha (2011) are quite high and thus include substantial area of agroforestry. The forest cover estimate of 69.20 m ha (ref. 3) is about 5 m ha more than the forest area of 63.77 m ha reported by the Ministry of Agriculture in 1977 based on revenue records[5]. The inclusion is likely because forest cover assessment carried out by FSI[3] using satellite data includes all land comprising an area of 1.0 ha and more with tree canopy density of more than 10%, irrespective of land use and ownership. Thus the forest cover should include agroforestry, mainly agrisilviculture, block plantations and orchards on agricultural fields. Similarly, tree cover includes trees in village woodlots, homestead, scattered trees on farms, and trees along roads, canals and railway lines.

The accurate assessment of area under agroforestry can be done with the help of geospatial technologies as manual (traditional) methods of mapping are expensive and take a relatively long time. The geo-spatial technologies are the integrated use of Geographical Information System (GIS), Remote Sensing (RS) and Geographical Positioning System (GPS), and all three are used for different purposes during the area assessment. GIS is used for geo-referencing, masking of RS data and estimation of area; GPS is used for collecting reference data on agroforestry which is later used for signature creation and accuracy assessment, and RS data is used for land-use and land-cover analysis and delineation of desired features. However, using RS data for the estimation of agroforestry area is challenging as well as problematic for several reasons[6]. Use of geospatial technologies to estimate agroforestry area has been initiated by the National Research Centre for Agroforestry, Jhansi, using medium resolution data with a methodology in which areas under agroforestry, forest and plantation are separately identified. The methodology will be further refined for accurate assessment of area under agroforestry in the country.

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Decellularized heart: a step towards creating personalized bioengineered organs

Shortage of available organs for transplantation in end-stage organ failure has become a major challenge for organ transplantation. Annually, more than 1,000,000 patients die for the want of an organ. Further, in the case of patients who do receive organs, not all transplants are successful due to rejection and other complications. Even if a patient receives perfect match, it can still be rejected and he needs life-long use of immunosuppressors. With this background, for developing appropriate tissue engineering technologies, scientists are struggling to regenerate the whole organ.

Decellularized whole organ represents a new approach to provide three-dimensional architecture and complex natural heart extracellular matrix (ECM). The classical approaches for generating heart tissues have limited applications because of absence of three-dimensional architecture to support the rebuilding of muscles and vascular structures. Decellularization is an emerging technology to fulfil these promises. It is defined as the complete removal of cells and their components from an organ by means of perfusion with the effective specialized reagents without damaging the ECM and three-dimensional vascular architecture. A bioartificial organ developed by decellularized scaffold solves the problem of life-long use of immunosuppressants after organ transplant. It also reduces the risk of rejection, and preserves decellularized extracellular matrix and 3D-scaffold that provides important signal for the engraftment, survival and function of transplanted cells in the new-born organ. The vascular bed in the decellularized bioscaffold allows rapid delivery of oxygen and nutrients.

Discovery of stem cells has boosted confidence in creating bioartificial organs. The major limitations of stem cells are that they need the right architecture, environment and engraftment to perform the function. Ott *et al.*[1] published a landmark paper, which showed perfusion-decellularized bioengineered heart matrix by seeding cardiac and endothelial cells. To establish function, they maintained constructs in a bioreactor. By day-8 under physiological load and electrical stimulation, constructs could generate pump function in a modified working heart preparation. Following this, Ng *et al.*[2] implanted embryonic stem cells in decellularized rat heart. After 14 days, these developed into two different types of cells found in the heart: cardiac-marker expressing cells and endothelial or blood vessel cells. The cell-laden scaffold was then implanted back into the mouse, where it was observed to develop visible blood vessels which are critical for the transport of nutrients and oxygen to the heart, and has posed a major challenge in heart tissue engineering. In a recently published study, Lu *et al.*[3] have demonstrated that spontaneous contraction in bioengineered heart generates mechanical force and responsiveness to drugs. This study also showed that heart ECM promotes cardiomyocytes proliferation and myofilament formation from the repopulated human multipotential cardiovascular progenitor cells.

In summary, the concept of decellularized whole-heart bioengineering approach would revolutionize *in vitro* studies for early events of heart development, which after further advancements may find application in preclinical testing and development of personalized bioartificial heart.

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