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# Resource use and benefits of mixed farming approach in arecanut ecosystem in India

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ABSTRACT

An eight-year experiment studied the sustainability, profitability, interdependencies and ecosystem services of crop–livestock integration in an arecanut plantation (ABMS) in humid tropics of India during 2007–2014. Arecanut registered similar kernel yields in both sole and intercropped systems in all years. The sole Napier Bajra Hybrid (NBH) recorded significantly higher green fodder yield than intercropped NBH. There was 5–47% yield reduction in intercropped NBH in different plantations over sole NBH on unit area basis. The total standing carbon stocks were significantly higher in arecanut + fodder system (210–228 t $ha^{-1}$) than arecanut sole and fodder sole. Total water use was 47 to 50% higher in arecanut sole (2340–3280 $m^3$) compared to ABMS (1178–1546 $m^3$) per unit area. The contribution of livestock to total outflows was high (82 to 87%) from 2008 to 2014 except in establishment year of dairy unit (54%). On an average, organic waste recycling potential of arecanut + dairy unit was 13.7 t $ha^{-1}$ and dairy unit alone contributed to 87% of the manure production. Total nutrient supply from ABMS after recycling to the system was estimated at 218 kg N, 51.8 kg P and 33 kg K that can meet N and P demand of 1.7 and 2.2 ha of arecanut, respectively. The farm gate nutrient surplus was five times higher than utilization in ABMS that enables farmers to earn higher profits. The use of hard laterite soil for livestock enterprises like dairy, fishery and fodder cultivation resulted in improved resource use efficiency and profits per unit area per unit time. Dairy was economical under all scenarios due to on-farm fodder availability throughout the year. Our main recommendations are to include livestock components in arecanut ecosystem to adapt to climate change scenario, to provide ecosystem services and to reduce ecological imbalances arising due to continuous cultivation of perennial crop.



## 1. Introduction

Agriculture is affected by several problems due to climate change, degradation of natural resources, proliferation of pests and diseases, market fluctuations and policy changes (MA, 2005; Pretty, 2008; Place and Mitloehner, 2010). It is necessary to devise suitable management strategies to adapt to these challenges especially in the tropics. Shaner et al. (1982) stated that farming systems approach addresses the problems of complex, marginal, diverse and risk prone agriculture. Integration of crop and livestock systems is one of the several farming strategies to restore agricultural diversity and to improve ecosystem services (Altieri, 2001; Magdoff, 2007). Integrated farming systems allow intensification of production and income, reduce adverse environment impact and benefit poor farmers (Edwards, 1998; Costa-Pierce, 2002; Devendra and Thomas, 2002; Karim, 2006). Mixed crop–livestock systems are favoured due to availability of resources, recycling of nutrients among farm components and reduced fluctuations in cash flows (Prein, 2002; Bell and Moore, 2012). The complementary role of different components of mixed crop–livestock farming on small land holdings of East Africa is reported (Tittonell et al., 2005). Thus, integrated crop–livestock systems are regaining interest worldwide for their economic and environmental advantages (Russelle et al., 2007; Wilkins, 2008; Ryschawy et al., 2012; Lemaire et al., 2014). Australian farmers are motivated by the risk mitigation benefits of mixed farming to dampen fluctuations in income as a result of both price and climate variability (Bell and Moore, 2012). Integrated farming systems that include semi-intensive aquaculture can be less risky because of synergism among enterprises, diversity in produce and environmental soundness (Devendra, 2002).

The systematic research work on mixed farming systems is limited in India (Maheswarappa et al., 2001; Jayanthi et al., 2002). About 85% of the land holdings are small and marginal and the average size of land holding is 1.16 ha in India (NABARD, 2014). Demand for livestock products is increasing rapidly in the tropics and the contribution of animals to the total income in smallholder mixed farming systems is as high as 64–70% for cattle and small ruminants (Delgado et al., 1999; Devendra, 2002). Global aquaculture is now the fastest growing

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food production sub-sector in many countries. Food security, rural development, and poverty alleviation are closely linked. Most of the farmers in India have small fragmented land holdings where modern large scale production technologies with large input requirements do not offer any solution to their problems. It is also increasingly realized that rural people do not depend for their livelihood on the agricultural sector alone, but rather on a range of livelihood options, which together offer their families food security and reduce vulnerability to conditions over which they have no control. These marginal farmers have livestock in the form of few numbers of cattle or a few pigs, a small flock of ducks or chicken and no doubt a surplus family labour where females and children of the house can work all day long.

This emphasizes the need for supplementing livestock based activities with crop based agricultural activities in small and marginal holdings. The production system at present is virtually traditional monocropping of plantation crops like arecanut, coconut and cashew in humid tropics of India, which are ecologically sensitive regions due to inherent climatic and soil constraints. Plantation crops are highly economical, but adoption of farming systems is necessary due to recurring problems like weather aberrations, soil fertility imbalance, yield variability, price fluctuations, and pest and diseases.

Arecanut (*Areca catechu* L.) is a commercially and socially important non-food crop in South-east Asia. In the world scenario, India accounts for the largest acreage of arecanut (0.446 m ha, GOI, 2014). Though the dry kernel is the main economic part, all parts of the palm can be utilized efficiently by value addition (Chowdappa et al., 1999; NIANP, 2011; Sujatha et al., 2015). Farmers' production goals in plantation belt are generally geared at high output/input ratios. But profits are reducing due to stagnant productivity (1200–1292 kg $ha^{-1}$) and increasing cost of production. Cropping system approach is followed in arecanut with highly competitive crops such as cocoa, banana, and coffee and yield losses are reported in all component crops due to improper management. Higher resource use efficiency and net income are reported due to nutrition, irrigation and intercropping in arecanut (Bhat and Sujatha, 2006; Bhat et al., 2007; Sujatha and Bhat, 2010; Sujatha et al., 2011a; Sujatha and Bhat, 2013). But it is very difficult to enhance the farm family income unless crop based agriculture is supplemented with integrated animal based enterprises. Adoption rate of arecanut based farming system is less in small and marginal farms compared to medium and large farmers (Jayasekhar, 2011).

Research, policies and interventions on the farm based on sound understanding of small-scale mixed farming systems will be more effective in South Asia (Thomas et al., 2002). The greatest challenge confronting the livestock systems of Asia is insufficient availability of animal feeds, both in terms of quantity and quality (Thomas et al., 2002). Arecanut is an irrigated crop and has lot of potential for inclusion of fodder crops and livestock components in it's ecosystem. Green fodder availability is plenty in plantation belt due to heavy rainfall but dairy is not treated as a business enterprise but practiced only for meeting the needs of household on a small scale. While talking of importance of fish farming in rural development in India, presently the greatest attention is being paid on the integrated approach of fish farming with agriculture and livestock. Promotion of integrated aquaculture with crops and livestock requires consideration of both bio-physical and socio-economic contexts (Nhan et al., 2007). Freshwater aquaculture contributes to over 95% of the total aquaculture production in India. This enterprise has tremendous scope in West Coast of India due to availability of water and difficulties in fishing during monsoon season. Despite the envisaged benefits of mixed cropping systems, an understanding of agro-ecosystem is most important for developing efficient farming systems with less dependence on external inputs. The information on the resource use and economic impact of integrating livestock components in perennial crop systems is scanty in India. With this background, the study on arecanut based mixed farming system was initiated with a primary objective to develop suitable models for different land holdings based on assessment of resource use efficiency, interdependencies, soil fertility and economic sustainability over a period of time.

## 2. Materials and methods

### 2.1. Details of experimental site

The research work was carried out at Regional Station of ICAR-Central Plantation Crops Research Institute, Vittal, Karnataka, India (12° 15'N latitude and 75° 25'E longitude, 91 m above sea level) during 2007–2014. The average rainfall per annum at this location is 3670 mm. The annual rainfall varied from 2600 mm to 3950 mm during the experimental period. South-west monsoon contributes about 80% of the total rainfall during June–September. Mean temperature ranges from 21 °C (minimum) to 36 °C (maximum). The average relative humidity varies between 61 and 94%. The soil of the experimental site is sandy clay loam (laterite) with a pH of 5.2–5.6 and high soil organic carbon (>2% in arecanut plantations) at 0–30 cm soil depth. The soil organic carbon status is less than 1% in hard laterite soils. The mixed farming model was established with components like arecanut sole, fodder sole, arecanut + fodder, dairy and fishery in a phased manner as initiation of complete model at a time would be difficult for small and marginal farmers. Fodder sole was included as a measure to ensure continuous fodder supply and to utilize hard laterite soils. The topography is undulating in humid tropics and hard laterite soils are seen in pockets that are formed due to heavy rainfall leading to continuous erosion and hardness of both surface and subsurface. The layout of arecanut based farming system model with different components is depicted in Fig. 1.

### 2.2. Arecanut component

Arecanut plantations of different age groups (2.7 m X 2.7 m spacing) with the presence of shade trees on South-west side were selected for the study. Arecanut needs shade on South-west side to avoid damage due to sun scorching. In 2007, 21-year-old arecanut plantation with an area of 0.24 ha (plantation 1 with 328 palms) was selected for studying the performance of Napier Bajra hybrid (NBH). Simultaneously another plantation of the same age and area (plantation $1_A$ with 328 palms) was also selected for only screening different fodder crops in 2007. In 2008, new arecanut plantation was established in 0.22 ha (plantation 2 with 300 palms) on a plot with slope of 3–10% and equal area was delineated for intercropping of fodder and sole crop situations. Fodder crop was intercropped simultaneously in plantation 2. It was contemplated to select another plantation with higher light availability for intercropping of fodder crop based on the results obtained from plantations 1 and 2. In 2012, 14-year-old arecanut plantation (0.21 ha, plantation 3 with 288 palms) with the presence of *Casurina* shade trees was selected. About 15 random sampling units were selected in each plantation for comparing yield and other parameters between sole arecanut and arecanut intercropped with fodder. For sampling purpose, two rows of arecanut palms on either side of the fodder crop in intercropped system and single row of arecanut in sole system were considered. Thus, the number of palms varied in sampling units of sole arecanut and arecanut + fodder system. In plantations 1 and 3, each random sampling unit consisted of 14 palms in intercropped situation and 6 palms in sole cropped situation. In plantation 2, each sampling unit consisted of 10 palms in both cropping situations.

Standardized management practices were followed for arecanut (Bhat and Sujatha, 2004). Farm Yard Manure (FYM) was applied @ 12 kg per palm every year before initiation of experiment. The nutrient composition of FYM was estimated as 0.5% N, 0.12% P and 0.45% K. However, the quantity of FYM application to the palms was adjusted with recycling of cow dung manure from dairy after initiation of the experiment. Arecanut was irrigated with sprinklers equivalent to 100% pan evaporation ($E_p$) during post monsoon season and thus there was