# SOIL MOISTURE, CROP GROWTH AND YIELD OF MAIZE AS INFLUENCED BY *Albizia saman* AGROFORESTRY SYSTEM

**Rex Immanuel, R., M. Thiruppathi, G.B. Sudhagar Rao, M. Saravanaperumal & J. Nambi**
Department of Agronomy, Faculty of Agriculture, Annamalai University,
Annamalai nagar, Tamilnadu, India – 608002

Received: January 05, 2019 Accepted: February 06, 2019

***ABSTRACT:*** *A field experiment was conducted at Annamalai University Experimental Farm, Annamalainagar during 2014 – 15, to examine the effect of Albizia saman (Jacq. Mull) (rain tree) bund plantings on the performance of soil moisture content and the growth and yield of maize (Zea mays). The results revealed that, the soil moisture content was less nearer to the A. saman bund plantings (3m distance), whereas after that it was progressively increased and attained the maximum at outer tree canopy cover area (9 m distance), and afterwards declains gradually. Regarding the aspects, the north east and north west aspect registered more soil moisture than the other aspects. The maximum LAI, biological yield and grain yield was recorded at 9 m distance from the base of the A. saman trunk. In north west aspect the maize growth was better and recorded maximum LAI, biological yield and grain yield.*

***Key Words:*** *Agroforestry, Albizia saman, leaf area index, N – fixing tree, tree-crop interactions.*

## 1. INTRODUCTION

Exploration of interactions between woody perennial and annual crop components is the solution to the successful sustainable way of land utilization in intensive cropping system. Accordingly, a healthier understanding of the interactions provides a vanguard improvement for traditional, as well as evolving economically viable and environmentally healthy agroforestry systems. The current food deficit is like to be increased further with decreasing land: man ratio. As a result of urbanization, industrialization and intensive cropping with use of high input technologies, the country has been facing acute shortage of timber, fuel wood and most essential tree based produces. Thus, it appears that there is a huge gap between supply and demand of forest products. Agroforestry has attracted significant attention in recent years because of its potential to maintain agricultural productivity in areas where high energy input, large scale agriculture is impractical.

Agroforestry systems are multifunctional land use systems where woody perennials are deliberately integrated with the agricultural crops and or livestock rearing under the same unit of land management either at the same time or in sequence. These land use systems diversify income for households and communities besides healthier soil fertility, improved water quality, enhanced biodiversity and carbon sequestration, and providing other positive environmental outcomes such as climate change adaptation (Nair, 2011, Luedeling *et al*., 2014, Waldron *et al*., 2017). There were several prominent agroforestry systems practiced by the farmer's such as bund plantings, boundary plantings, scattered tree plantings, agrisilviculture, silvihorti systems, and silvipastoral systems *etc*. (Doddabasawa, *et al*. 2017).

The challenge in agroforestry systems is to find out the ways to retain the positive effects of tree species while limiting the negative effects of below ground competition with annual crops (Lott *et al*., 2000). Rain tree (*Albizia saman* (Jacq.) Merr.) being deciduous nitrogen fixing tree and suited well to companion crop for ensuring food production and also enhance economic returns to the growers. *A. saman* has been recognized as a leguminous tree species with potential in agroforestry (Nair *et al*. 1984 and Durr, 2001). *A. saman is* known to nodulate and effective nodulation by the appropriate N-fixing rhizobia is one of key factor in the adaptation to varied climate and soils (Qadri and Mahmood, 2003; Qadri *et al*. 2007, Azad *et al*., 2013). The worth of the tree as a pasture species is enhanced by observations of increased growth of herbage beneath its canopy (Morrison *et al*. 1996). Likewise, Durr and Rangel (1995) measured above ground herbage production under and outside the canopy of *A. saman* significantly improved the productivity of grassland in tropics, and found that the sub canopy production was twice that of the open grassland. Leaf fall at sowing poses physical barrier to seed germination and light to developing seedlings influence the crop growth (Chauhan *et al*., 2012).

Rice-based cropping systems are of immense importance for food security in India, providing, 85 per cent of the total cereal production and 60 per cent of the total calorie intake (Timsina and Connor, 2001). The conventional system though profitable has not remained sustainable as it has resulted in lowering ground water table, development of compact sub soil layer, nutrient imbalance, sustainability of future agriculture and ecological balance. Maize (*Zea mays* L.) has become a most important fast growing cash crop play significant role in food processing, poultry, dairy and ethanol industry (Wahi, 2014).

The majority of maize farming (60%) is done by marginal farmers who have acreage of less than one hectare. In general, individual land holding in India is significantly smaller than the major agri-based countries and this holds true in case of maize farming as well. Maize can be grown in rice-maize cropping sequences in water deficit command areas. Crop yield increases are common under well managed agroforestry systems due to a combination of improvements in soil fertility and enhances soil water content resulting from reduced evaporation (Rao *et al*., 1998). However, the increased tree cover may generate competition for water and nutrients between trees and crops (Ong *et al*., 2000). Competition for soil moisture may reduce plant growth and yield of maize in agroforestry systems relative to sole cropping. The interactions in agroforestry systems are continuous rather than seasonal as in annual systems. Keeping these in view the present investigation was formed to test the hypothesis that the microclimate created by *Albizia saman* under bund plantings would favourably effect the soil moisture content and its effect on growth and yield of associated maize crop during *Zaid* season.

## 2. MATERIALS AND METHODS

The field experiment was conducted at Annamalai University Experimental Farm, Annamalai Nagar, Tamil Nadu during *Zaid* (Summer) season of 2014 – 15. The experimental farm is geographically located at 11º24' N latitude and 74º41' E longitude at an altitude of + 5.79 m above mean sea level and 15 km away from the Bay of Bengal coast. The weather at Annamalainagar is moderately warm with hot summer months. The mean annual rainfall received is 1500 mm with a distribution of 1000 mm during North East monsoon, 400 mm during South West monsoon and 100 mm during hot weather period and spreading over 60 rainy days. During the cropping period the maximum temperature ranges from 27.8°C to 35.4°C with a mean maximum of 30.6°C, while the minimum temperature fluctuates between 17.7°C and 26.2°C with a mean of 21.7°C. The average relative humidity is 87.9 per cent. The mean hour of bright sunshine per day during study period is 8.18. The rainfall received during cropping period is 32mm with 4 rainy days. The mean evaporation during the study period is 3.7 mm per day.

The soil of the experimental field is clay in texture. The nutrient status of the experimental soil was low in available nitrogen, medium in available phosphorus and available potassium. The experimental field was irrigated with water lifted from Uppanar channel, running along the southern boundary of the experimental farm.

The experimental site consisted of 35 years old *Albizia saman* bund plantings with at 15 m apart in east west direction. Maize hybrid (Nileesh 51) was cropped on the northern side of the bund plantings. The tree rows were oriented east–west to minimise the shading effect on agricultural crops. Different observation plots of 2 x 2 m were laid out at 3m interval [A – Inner canopy cover area (3 m), B – Middle canopy cover area (6 m), C – Outer canopy cover area (9 m), D – Canopy cover free area (12 m)] on north, north east, north west from the bund plantings (Fig. 1).

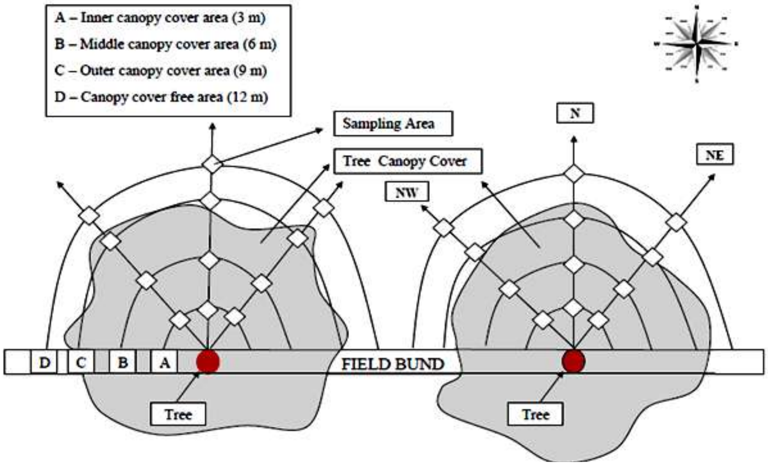


**Fig 1. Layout showing tree canopy cover along with soil and plant sample observation transects**

The *A. saman* trees were measured for their height, girth at breast height (1.37 m above the ground level) and crown spread (Table 1).

**Table 1. Average growth parameters of *A. saman* bund trees**

| Tree height (m) | Girth at breast height (m) | Crown spread (m) | | | |
|---|---|---|---|---|---|
| | | North | South | East | West |
| 28.0 | 2.6 | 8.4 | 9.2 | 9.6 | 10.3 |

The soil samples were randomly collected from 0-20 cm depth from the center of each observation plot using soil auger. The soil samples were collected with one week interval for the estimation of soil moisture content. The soil samples were immediately weighed using mobile digital weighing balance to obtain the fresh weight of the soil. Later the soil samples were kept in the oven at 105 $^0$C until constant weight was achieved and weighed. Then the soil moisture content was calculated using gravimetric method.

The experimental fields were ploughed with tractor drawn cultivator. The clods were broken, field was leveled and the ridges and furrows were formed. A seed rate of 15 kg ha $^{-1}$ was followed. The seeds were dibbled @ one seed per hole at a depth of two cm, with a spacing of 60 x 30 cm. Recommended dose of fertilizer @ 135:62.5:50 kg of N, $P_2O_5$ and $K_2O$ ha$^{-1}$ was applied. Nitrogen was applied in the form of urea (46% N), phosphorus as single superphosphate (16% $P_2O_5$) and potash as muriate of potash (60% $K_2O$). The entire dose of phosphorus was applied basally before planting. Potassium was applied along with nitrogen in three equal splits (basal, grand vegetative and flowering stages).

Gap filling was done on 12 DAS so as to maintain uniform plant population. Irrigation was given immediately after sowing with due care to avoid excess flooding of water. Life irrigation was given 5$^{th}$ day of sowing. Subsequent irrigations were given at 15 days interval and when as required to the crop. Two hand weedings were done at 20 and 45 DAS. Prophylactic plant protection measures were taken up against pests and diseases as per the recommendation. The cobs were harvested from each treatment plot separately, sun dried, threshed, cleaned and stored at 12 per cent moisture level.

In each plot, five sample plants were chosen at random and tagged and were subjected to all biometric observations. The biometric observations were made and recorded at different growth stages. The mean values of biometric observation were documented for statistical analysis. The length and breadth of the fourth leaf from top in sample plants were measured at tasseling stage. The LAI was worked out as out lined by Francis *et al*. (1969).

The crop biomass was estimated by using the plant samples, which were drawn at each observation. Three plants from each sampling area were selected by cutting close to the ground level. These plants were first air dried in shade and then oven dried at 80 ± 5°C until constant weight arrived. The oven dry weight of plant samples was computed and recorded as t. ha$^{-1}$. The biological yield and grain yield was recorded from 4 m$^2$ area at 3, 6, 9 and 12 m distance from the base of the *A. saman* trees on each aspect and expressed in t ha$^{-1}$.

## 3. RESULTS

### 3.1. Effect on soil moisture content (%)

The highest soil moisture content of 30.64 and 28.48 per cent respectively were at seedling and grand growth stage at open canopy area (12 m distance) (Table 2). The maximum soil moisture content of 30.52 and 28.02 per cent at seedling stage and grand growth stage, respectively were recorded at north east aspect.

**Table 2. Effect of *A. saman* on soil moisture content (%) at vegetative stage of maize**

| Aspect/ Distance | Seedling stage | | | | | Grand growth stage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3m | 6m | 9m | 12m | Mean | 3m | 6m | 9m | 12m | Mean |
| **North** | 26.30 | 30.11 | 30.30 | 29.78 | 29.12 | 24.15 | 27.43 | 25.29 | 27.31 | 26.05 |
| **North East** | 29.59 | 31.03 | 30.59 | 30.88 | 30.52 | 26.43 | 27.38 | 30.12 | 28.15 | 28.02 |
| **North West** | 29.09 | 28.07 | 29.09 | 31.28 | 29.38 | 25.93 | 25.87 | 28.95 | 30.00 | 27.69 |
| **Mean** | 28.32 | 29.74 | 29.99 | 30.64 | | 25.50 | 26.89 | 28.12 | 28.48 | |

The highest soil moisture content of 26.17 and 23.83 per cent at tasseling and silking stage were recorded in outer canopy area (9 m distance) (Table 3). In respect to aspect, north east aspect in tasseling and silking stage registered highest soil moisture content of 24.28 and 22.88 per cent, respectively.

**Table 3. Effect of *A. saman* on soil moisture content (%) of maize field at flowering stage**

| Aspect/ Distance | Tasseling stage | | | | | Silking stage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3m | 6m | 9m | 12m | Mean | 3m | 6m | 9m | 12m | Mean |
| North | 18.66 | 23.39 | 25.93 | 24.00 | 23.00 | 20.00 | 19.66 | 25.93 | 22.39 | 22.00 |
| North East | 23.85 | 22.80 | 27.15 | 23.31 | 24.28 | 21.15 | 23.95 | 23.43 | 23.00 | 22.88 |
| North West | 23.95 | 24.00 | 25.43 | 22.15 | 23.88 | 18.65 | 23.05 | 22.15 | 22.80 | 21.66 |
| Mean | 22.15 | 23.39 | 26.17 | 23.15 | | 19.93 | 22.22 | 23.83 | 22.73 | |

The maximum soil moisture content of 22.15, 28.33 and 29.09 per cent at soft and hard dough stage and ripening stage respectively were recorded in outer canopy area (9 m distance) (Table 4 & 5). In respect to aspect, north east aspect registered the highest soil moisture content of 21.31, 26.33 and 26.77 per cent, respectively.

**Table 4. Effect of *A. saman* on soil moisture content (%) of maize field at reproductive stage**

| Aspect/ Distance | Soft-dough stage | | | | | Hard-dough stage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3m | 6m | 9m | 12m | Mean | 3m | 6m | 9m | 12m | Mean |
| North | 19.39 | 21.93 | 20.66 | 19.46 | 20.36 | 22.15 | 22.29 | 27.40 | 24.85 | 24.17 |
| North East | 20.00 | 20.43 | 23.65 | 21.15 | 21.31 | 22.93 | 25.95 | 29.45 | 27.00 | 26.33 |
| North West | 21.55 | 22.15 | 22.15 | 19.00 | 21.21 | 23.43 | 27.42 | 28.15 | 25.10 | 26.03 |
| Mean | 20.31 | 21.50 | 22.15 | 19.87 | | 22.83 | 25.22 | 28.33 | 25.65 | |

**Table 5. Effect of *A. saman* on soil moisture content (%) of maize field at ripening stage**

| Aspect/Distance | 3m | 6m | 9m | 12m | Mean |
|---|---|---|---|---|---|
| North | 24.45 | 27.68 | 28.15 | 26.38 | 26.67 |
| North East | 26.76 | 25.00 | 29.45 | 25.87 | 26.77 |
| North West | 25.15 | 26.78 | 29.67 | 25.15 | 26.69 |
| Mean | 25.45 | 26.48 | 29.09 | 25.80 | |

### 3.2. Effect on leaf area index (LAI)

Leaf area index (LAI) explains how efficiently the available resources are used for metabolic activities by growing crop in the field. It was recorded that the LAI of maize crop varied from 2.98 to 5.98 (Table 6). Significantly maximum LAI of 5.37 was recorded at 9 m distance from the base of *A. saman* tree. It was also observed that north west aspect registered the maximum LAI of 4.77.

### 3.3. Effect on biological yield of maize tonnes ha$^{-1}$

It was found that the biological yield of maize crop varied from 6.2 tonnes ha$^{-1}$ to 9.2 tonnes ha$^{-1}$ (Table 7). The maximum biological yield of 8.0 tonnes ha$^{-1}$ was recorded at 9m distance. Regarding the aspect, North West aspect registered the maximum biological yield of 7.8 tonnes ha$^{-1}$.

**Table 6. Effect of *A. saman* bund planting on leaf area index (LAI) at flowering stage of maize**

| Aspect/Distance | 3m | 6m | 9m | 12m | Mean |
|---|---|---|---|---|---|
| North | 4.93 | 5.10 | 5.48 | 3.23 | 4.69 |
| North East | 5.70 | 4.38 | 5.81 | 2.98 | 4.72 |
| North West | 4.52 | 5.98 | 4.82 | 3.76 | 4.77 |
| Mean | 5.05 | 5.15 | 5.37 | 3.32 | |
| | Distance | | Aspect | | |
| SE± | 0.31 | | 0.17 | | |
| CD at 5% | 0.95 | | NS | | |

**Table 7. Effect of *A. saman* bund planting on biological yield of maize (t ha$^{-1}$)**

| Aspect/Distance | 3m | 6m | 9m | 12m | Mean |
|---|---|---|---|---|---|
| North | 6.8 | 6.5 | 6.3 | 6.5 | 6.5 |
| North East | 7.0 | 7.9 | 8.5 | 6.7 | 7.5 |
| North West | 7.6 | 8.3 | 9.2 | 5.9 | 7.8 |
| Mean | 7.1 | 7.6 | 8.0 | 6.4 | |
| | Distance | | Aspect | | |
| SE± | 0.12 | | 0.27 | | |
| CD at 5% | 0.35 | | 0.62 | | |

### 3.4. Effect of *A. saman* bund plantings on grain yield of maize (tonnes $ha^{-1}$)

The grain yield of maize varied from 1.9 to 3.5 tonnes $ha^{-1}$. The maximum grain yield of 3.0 tonnes $ha^{-1}$ recorded at outer canopy level (9 m distance). Likewise the highest grain yield of 2.9 tonnes $ha^{-1}$ was recorded at North West aspect.

**Table 7. Effect of *A. saman* bund plantings on grain yield (t $ha^{-1}$) of maize**

| Aspect/Distance | 3m | 6m | 9m | 12m | Mean |
|---|---|---|---|---|---|
| **North** | 2.1 | 2.4 | 2.4 | 2.2 | 2.3 |
| **North East** | 2.3 | 2.8 | 3.2 | 2.1 | 2.6 |
| **North West** | 2.9 | 3.1 | 3.5 | 1.9 | 2.9 |
| **Mean** | 2.4 | 2.8 | 3.0 | 2.1 | |
| | Distance | | Aspect | | |
| **SE±** | 0.07 | | 0.04 | | |
| **CD at 5%** | 0.18 | | 0.15 | | |

## 4. DISCUSSION

### 4.1. Soil moisture content

In semiarid region availability of soil moisture is a primary factor for contributing plant growth and productivity processes. *In situ* soil moisture retention in the rhizosphere of crop plant is one of the essential factors which can be achieved through agroforestry practices (Singh *et al*., 2003). The soil moisture content was spatially increased up to 9 m distance from the base of the tree and then declained beyond the canopy cover of 9 m. During the study period the *A. saman* trees were under deciduous nature. Leaf fall acted as effective soil mulch up to 9 m distance, and act as evaporation loss preventant and subsequently conserved the soil moisture effectively (Plate 2). The natural mulching caused by the fallen tree leaves (Plate 3), reductions in soil evaporation resulting from shading by the tree canopy and reduced air movement through the understory environment, alterations in microclimatic conditions arising from reductions in air temperature and saturation deficit which decrease crop water use (Jonsson *et al*., 1999).

Beyond the canopy cover of 9 m distance from the bund plantings, the soil moisture per cent was lowered as compared to other sampling distances. This might be due to the warming of the upper soil profile owing to high temperature and the depletion of soil moisture beyond the tree canopy level casused drastic depletion in soil moisture at greater level. One of the most widely acclaimed advantages of agroforestry is its potential for conserving the soil moisture (Nair, 1993). In traditional agroforestry systems, trees are used to maintain the hydrological balance and conserve the soil, moreover the tree-crop combination used the soil water more efficiently for its growth and development than the sole cropping (Kumar and Yadav, 2003).

The average soil moisture content up to 12 m distance from *A. saman* bund plantings during seedling stage was high due to lesser evapotranspiration then it declains gradually and attains maximum reduction during flowering (tasseling and silking) and soft dough stages. During this stage, peak consumption of soil moisture occurred by the maize plant. The leaf shedding during winter in the sheltered area resulted in good availability of soil moisture. Leaf fall before sowing gets incorporated in soil and enhanced the soil organic matter but after it interfere in the emergence and/or growth of weeds. Further the soil moisture also guarded by active mulch material during the later stages.

### 4.2. Leaf area index and biological yield of maize crop

In general LAI and biological yield of maize gradually increased from 3m distance and reached the maximum up to 9 m distance *i.e.* up to the outer canopy cover of the *A. saman* bund plantings, and after that it declains. The observations on LAI revealed that the growth of the crop plants were also good as towards the outer canopy level in all the aspects from the field bund plantings. This resulted in overall increase in the biological yield of maize. The variable influence on LAI and biological yield can be attributed to micro-site enrichment caused by favourable environment due to adequate resources and leaf litter addition by the *A. saman*.

Aspect-wise, north west aspect recorded maximum LAI and biological yield, whereas, on north aspect had minimum LAI and biological yield. The north west aspect allows maximum light on the field throughout the day. The physical environment gets improved leaf litter fall and thus resulting in more efficient nutrient addition in the soil. Plant nutrient uptake increased adjacent to the tree rows due to leaf biomass addition and N fixation (Sharma and Dhadwal, 2007).

### 4.3. Yield of maize crop

Perusal of results revealed variable influence on yield at different distances, which can be attributed to micro site enrichment caused by favourable environment and conservation of soil moisture due to leaf litter addition. *A. saman* which showed the lowest shade effect by losing its leaves in crop growth period resulted in a net positive effect on the transmission of more quantum of light to maize crop which ultimately favoured for accumulation of higher photosynthates and contributed maximum grain yield. Intercepted radiation by the crop plant relates to seed yield of maize.

Another one of the major effects of trees in agroforestry system is reduction of soil moisture loss and suppression of weeds compared with pure cropping. This is due to the complementary processes of mulch from leaf fall providing a ground cover (Kang, 1993); and less competing with weeds for other growth resources (Rippin *et al*., 1994). Over the years, trees might reduce the weed seed bank in the soil, especially leaf fall in deciduous trees, which would smother weeds, prevent further addition of weed seeds, and reduce seed viability by preventing germination. The relative importance of mulching effects depends on tree species.

The changes in micro environment under tree canopy (soil moisture, temperature, *etc*.), proliferation of root system and enhanced biological activity favoured the productivity of associated agricultural crop. An alternative hypothesis to explain enhanced yield is due to the raised nutrient levels arising from the tree's abundant litter. This is in line with the findings of SaeLee et al. (1992), who revealed that higher nutrient content in the canopy cover of *A. saman* over outer canopy area. Kolapo *et al*. (2014) reported that the application of 2.5 t ha$^{-1}$ *A. saman* leaves as source of organic significantly increased the growth of maize.

## 5. CONCLUSION

The results of the study indicated that agroforestry is a significant component in the agricultural landscape of any region. However, bund planting agroforestry system, the soil moisture content was progressively increased and attained the maximum at outer tree canopy cover area (9 m distance), and thereafter declains (12 m distance) gradually in open area (non canopy cover) in maize field. As far as influence of aspect on soil moisture content is concerned, the north eastern aspect acquired more soil moisture than the north aspect. Significantly higher LAI, biological yield and grain yield of maize were noticed under the canopy of *A. saman* from 3 m to up to 9 m distance apart the trunk of *A. saman*. Hence, it can be concluded that diversifying agricultural production by including with suitable multipurpose tree species like *A. saman* can lead to conserving soil moisture and increasing productivity of crops.

## REFERANCES

1. Azad, M.S., Mondol, S. and Matin, M.A. 2013. Functional relationships of nodulation response and biomass production at nursery stages of two fast-growing, leguminous multipurpose tree species in Bangladesh: Albizia saman and Leucaena leucocephala. Forest Science and Practice. 15(4): 274–285, https://doi.org/10.1007/s11632-013-0416-2
2. Chauhan, S. K., R. Sharma, S.C. Sharma, N. Gupta and Ritu, 2012. Evaluation of Poplar (Populus deltoides Bartr. Ex Marsh.) Boundary Plantation Based Agri-silvicultural System for Wheat-Paddy Yield and Carbon Storage. Int. J. Agri. Forestry, 2(5): 239-246.
3. Doddabasawa , M., M. Murthy and B.M. Chittapur, 2017. Assessment of Tree Diversity in Agroforestry Systems under Irrigated Ecosystem. Int.J.Curr.Microbiol.App.Sci., 6(10): 3111-3127
4. Durr, P. A. 2001. The biology, ecology and agroforestry potential of the raintree, Samanea saman (Jacq.) Merr. Agroforestry Systems, 51(3): 223–237, https://doi.org/10.1023/A:1010765022497.
5. Durr, P.A and Rangel, J. 1995. Increases in herbaceous production under the canopy of Samanea saman in a subhumid tropical grassland. Agroforestry Systems, 32: 204 – 208.
6. Francis,C.A., J.N. Rutager and A.F.E. Plamer. 1969. A rapid method of plant leaf area estimation in maize (Zea mays L.). Crop Sci., 9: 537 – 539.
7. Jonsson, K., Ong, C.K., and Odongo, J.C.W. 1999. Influence of scattered néré and karité trees on microclimate. Exper. Agric., 35: 39-53.
8. Kang, B.T. 1993. Alley cropping: past achievements and future directions. Agroforestry Systems, 23: 141–155
9. Kolapo, O. Kazeem, Wahab, M.K.A., Hossain, Md. Aktar, Adebola, Adegeye ,O., Ab. Shukor and N. Aini, 2014. Effects of Albizia saman (Jacq. Mull) leaf mulch on vegetative growth of maize (Zea mays L.) and soil chemical properties through biomass transfer. Research on Crops. 15 (4): 768-774.
10. Kumar, S. and Yadav, M.P. 2003. Effect of different moisture conservation practices on soil profile recharging and water use efficiency in silvipastoral system. Indian J. of Agroforestry 5(172): 55-59.
11. Lott, J.E., Howard, S.B., Ong, C.K and Black, C.R. 2000. Long-term productivity of a Grevillea robusta-based overstorey agroforestry system in semi-arid Kenya. 1. Tree growth. Forest Ecol. Manage. 139: 175–186.

12. Luedeling, E., R. Kindt, N.I. Huth and K. Koenig, 2014. Agroforestry systems in a changing climate – challenges in projecting future performance. Current Opinion in Environmental Sustainability. 6( 1): 1-7
13. Morrison, B.J., Gold, M.A and Lantagne, D.O. 1996. Incorporating indigenous knowledge of fodder trees into small-scale silvopastoral systems in Jamaica. Agroforestry Systems, 34: 101–117
14. Nair, P.K.R. 1993. An introduction to agroforestry. Kluwer Acad. Pub., London. In cooperation with ICRAF. pp 498.
15. Nair, P.K.R., 2011, Agroforestry systems and environmental quality: Introduction. Journal environmental Quality, 40:784-790.
16. Nair, P.K.R., Fernandes, E.C.M and Wambugu, P.N., 1984. Multipurpose leguminous trees and shrubs for agroforestry. Agroforestry Systems, 2: 145–163.
17. Ong, C.K., Black, C.R., Wallace, J.S., Khan, A.A.H., Lott, J.E., Jackson, N.A., Howard, S.B., Smith, D.M., 2000. Productivity, microclimate and water use in Grevillea robusta-based agroforestry systems on hillslopes in semi-arid Kenya. Agric. Ecosyst. Environ., 80: 121–141.
18. Qadri R and Mahmood A. 2003. Presence of rhizobia in the xylary elements of root nodules in Samanea saman (Jacq.) Merr. Pak. J. Bot., 35(5): 819–823.
19. Qadri R, Mahmood A and Athar M. 2007. Ultra-structural studies on root nodules of Samanea saman (Jacq.) Merr. (Leguminosae). Polish J. Microbiol., 56(3): 199–204.
20. Rao, M.R., Nair, P.K.R., and Ong, C.K., 1998. Biophysical interactions in tropical agroforestry systems. Agroforestry Systems, 38: 3–49.
21. Rippen, M., Hagger, J.P.H., Kass, D and Köpke, U. 1994. Alley cropping and mulching with Erythrina poeppigiana (Walp.) O. F. Cook and Gliricidia sepium (Jacq.) Walp.: effects on maize/weed competition. Agroforestry Systems, 23: 119–134
22. Sae-Lee, S., Vityakon, P and Prachaiyo, B. 1992. Effects of trees on paddy bund on soil fertility and rice growth in northeast Thailand. Agroforestry Systems, 18: 213–223.
23. Sharma, N.K. and K.S. Dhadwal, 2007. Growth and yield of wheat as affected by boundary plantation of Populus deltoides M. in western Uttar Pradesh. Indian For., 133: 899-908.
24. Singh, A., Singh, R. and Pannu, R.K. 2003. Effect of Eucalyptus plantation on moisture extraction pattern, water use and yield of wheat. Indian J. Agrofor., 5(1&2): 45-49., 55-59.
25. Timsina, J. and D.J. Connor, 2001. Productivity and management of rice-wheat cropping systems: issues and challenges. Field Crops Res., 69: 93-132.
26. Wahi, R. 2014. Indian Maize Scenario. India Maize Summit, 2014. National Commodity and Derivatives Limited, Ackruti Corporate Park, 1st floor, Near G.E. Garden, Kanjurmarg, Mumbai-78
27. Waldron, A., D. Garrity, Y. Malhi, C. Girardin, D.C. Miller and N. Seddon. 2017. Agroforestry can enhance food security while meeting other sustainable development goals. Trop. Conserv. Sci., 10: 1-6.

**Plate 1. *Albizia saman* bund plantings along with maize crop**

**Plate 2. Deciduous nature of *A. saman* during the beginning of maize cropping**

**Plate 3. Natural leaf mulching of *A. Saman* bund plantings (Up to 9m maize field)**

**Plate 4. Maize crop at 12 m distance exhibits poor performance**