Sustainability of rubber agroforestry strategies in boosting smallholders' resilience to cope with the realities of new global challenges

T.U. Esekhade* , *S.O.* Idoko, *Chioma U.* Abolo and *S.* Igberase

Rubber Research Institute of Nigeria, PMB 1049, Iyanomo, Benin City Nigeria.

Abstract. In the face of a global pandemic, the ever-present threat of climate change and the highly unstable economic and social global systems the resource poor smallholder farmer is increasingly finding it harder to meet with the daily challenges of sustaining the livelihood of the farmer and his family. This paper is a review of the challenges of smallholder's rubber farmers, strategies adopted to build the resilience of the farmers and technological adaptations to sustain the resilience of the smallholder's rubber farmers in Nigeria. The work looked at the manipulation of space or spacing techniques in rubber-based agroforestry systems, mixed farming in rubber production, cropping patterns, soil nutrient and weed management methods and socioeconomic benefits to the rubber smallholders. The results indicated that RBAF systems helped resource poor rural farmers increase family food supply, improved income and reduced the gestation period of rubber leading to improved livelihood. This results will help in attracting more smallholders to rubber plantation establishment, leading to increased national rubber production for local and international markets and increase industrial development in rubber and rubber related products.

Keywords: Rubber based agroforestry, smallholders, sustainability, resilience, climate change

1 Introduction

The current challenges of the smallholder rubber farmers in the face of global change are daunting. The situation in Africa and in particular Nigeria is far worse due to over aged and moribund plantations and the effect of price instability which is global in nature. Forg *et al.*, (2019) suggested that NR production, consumption, international price, crude oil and synthetic rubber prices were important factors affecting the NR prices instability in the global market.

The potential for growth in Nigeria lies in the revamping of rubber smallholdings, which in the past constituted 70 per cent of the total holdings. Presently there is an increase in the proportion of estates contribution to production in Nigeria than smallholdings.

* Corresponding author: esekhade.timothy@rrin.org.ng

The area under rubber smallholdings has experienced dwindling hectarage; this deficit in rubber production is attributed to the following incidence:
Abandoned plantation, conversion of plantation to arable farms and other non-agricultural activities and competition with other tree crops such as oil palm and cocoa. To reverse the trend smallholders' farmers, need to be organized into rubber comparatives and associations. Also, they should be encouraged to adopt the application of suitable farming systems such as intercropping at immaturity stage and mixed farming at canopy closure to stimulate their participation in rubber production.

Intercropping of rubber with arable crops has been found to be beneficial to the growth of rubber and capable of improving the economy of the rubber enterprise thereby reducing the need for subsidies and credit to rubber farmers [14, 5]. Rubber intercropping serves as additional sources of organic materials to the soil and help create a micro climate that leads to soil moisture conservation and subsequent encouragement of a more robust girth of young rubber saplings on the field [4, 12]. Intercropping of rubber with arable crops before rubber canopy closure helps reduce the cost of rubber plantation establishment by generating income to farmers during the period of rubber establishment and thus less the need for subsidies and credit to rubber farmers [2, 5].

Hence, a timely adoption of appropriate plantation management practices that is capable of utilizing the under-utilized land resources and increases the revenue base of the rubber farmer is important to the attainment of the drive to increase rubber production in Nigeria.

The effect of climate change on mankind, particularly the rural poor are quite obvious today. There is a growing demand for food, against a backdrop of rising global temperatures and changing patterns of precipitation, affecting trees and crop growth, as well as livestock performance, and the availability of water. The most effective way to reduce people's venerability to shocks and build their resilience is to improve their overall well- being. One way to do this is by improving rubber plantation productivity, providing off farm sources of income and improving access to markets. Therefore, agroforestry defined as the intentional use of trees in the cropping systems to increase farm productivity, diversify income sources and provide environmental services; can play an important role in helping smallholder rubber farmers, build resilience and reduce their vulnerability to global change in a sustainable way. Sustainability in the sense of rubber production in environmentally friendly or green activities that meets the needs of the present world without compromising the ability of the future generations to meet their own needs.

The objective of this paper was to review research and development strategies developed in Nigeria, aimed at the manipulation of the underutilized spaces within rubber plantations for rubber-based agroforestry and mixed farming systems to diversify sources of income and build farmers resilience to cope with the realities of new local and global challenges in Nigeria.

2 Challenges of smallholder farmers in Nigeria

Poor Access to Labour: Rubber is a high labour demanding crop and most of the operations especially tapping are very difficult to mechanize. In Nigeria this this problem is compounded by the fact that the rubber growing areas in Nigeria coincides with the oil producing Niger Delta region where youths prefer jobs in the high paying oil companies rather than engage in agriculture considered as dirty, laborious and non profiting.

High Cost of Transportation: The poor state of farm and feeder roads and the high cost of diesel combined to increase the cost of transportation to farmers and buyers of rubber products.

Poor access to certified rubber seedlings: Smallholders Farmers have difficulties in having access to certified rubber planting materials, due to costs and access to planting materials production centers. The only government establishment that produces planting materials at subsidize costs does not produce enough to meet the needs of smallholders.

Poor Access to Inputs: The population of farmers (especially smallholder farmers) who account for about 70% of domestic rubber production in the 1960s up to the 1980s has dwindled significantly due to lack of access to inputs such as fertilizers and budding/tapping instruments. Because of the inefficiency in the value chain structure resulting from the absence of value chain coordination, fertilizer neither gets to farmers at the right time and at affordable price.

Covid 19 pandemic: In a recent survey conducted amongst smallholder rubber farmers in Nigeria, the effect of the global pandemic on the availability of food, quality of food, medical cares, cost of transportation, house rent and electricity bills was serious to very serious on the livelihood of the smallholders. Also very serious is the effects of lack of movement, low price of rubber, poor sales, poor electricity supply and high cost of production.

Table 1. Effect of COVID 19 pandemic on smallholder's farmer's livelihood in some rubber growing states in Nigeria

	Very Serious	Serious	Not Serious	Not Decided
Availability of food				
Quality of food				
Medical Cares				
Lack/Cost of transportation				
House Rent				
Electricity Bills				

Table 2. Constraints due COVID 19 pandemic on smallholder's rubber farmers in some rubber growing states in Nigeria

	Very Serious	Serious	Not Serious	Not Decided
Lack of movement/Transportation problem				
Change in price/Low price				
Lack/inadequate labour				
Lack of Market/Poor sales				
Poor electricity supply				
High costs of production				

3 Technological adaptation to sustain the resilience of smallholder rubber farmers in Nigeria

3.1 Spacing techniques in rubber-based agroforestry system

The conventional spacing of rubber in Nigeria is 6.7 x 3.4m between and within lines. Rubber is also spaced at 2.5 by 8 meters within and between lines of rubber. Another spacing pattern is the double lines spacing, where rubber is spaced at 2.5 x 2.5m by 10.0m.

In all spacing patterns, there are usually large inter rows areas for intercropping. Depending on the type of crop being intercropped, a space of between 1.0 and 2.0m is maintained between rubber and the crops (Figure 1). Crops that are likely to shade young rubber and whose rooting systems proliferates very fast and long duration crops are planted further away from young rubber than do crops that do not have characteristics just mentioned. Cowpea, soybean, groundnut, maize, melon, Telferia, Sweet potato and pineapple are spaced at least 1.0m from young rubber, while crops such as cassava, yam, plantain, banana, cocoyam etc. are spaced at 1.5- 2.0m away from young rubber. Between 70 and 80 percent of the land is usually available for intercropping when crops are planted at 1.0 and 2.0m away from rubber saplings.

Farmers are at liberty to space the crops within the rubber inter rows. For example, cassava can be spaced at either 0.50 x 1.0m, 1.0 x 1.0m or 1.5 x 1.0m, while maize can be spaced at 0.25 x 0.75m, 0.50 x 0.75m or 0.60 x 0.90m, while maize/cassava can be spaced at either 0.50 x 0.75m/0.50 x 1.0m or 0.50 x 0.75m/1.0 x 1.0m. These crops may be rotated in different patterns as shown in Figures 2 - 4.

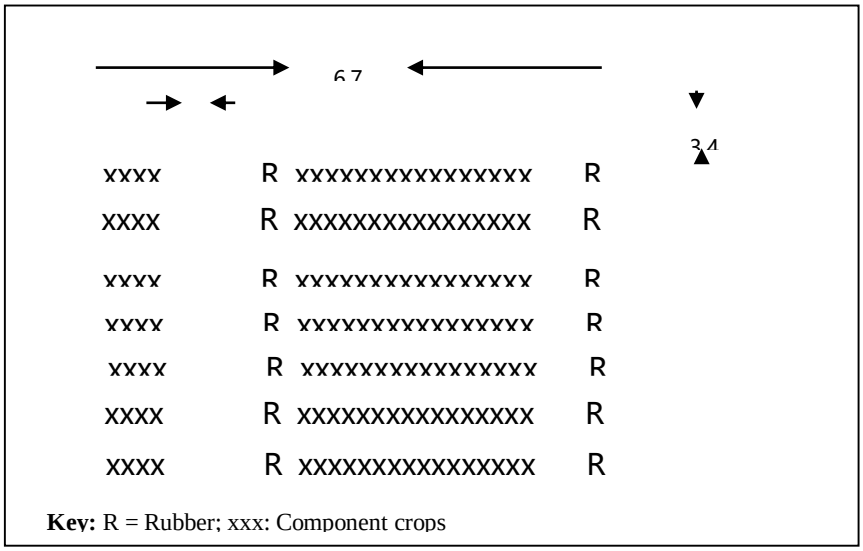

Fig. 1. Arrangement of rubber and component crops within rubber rows

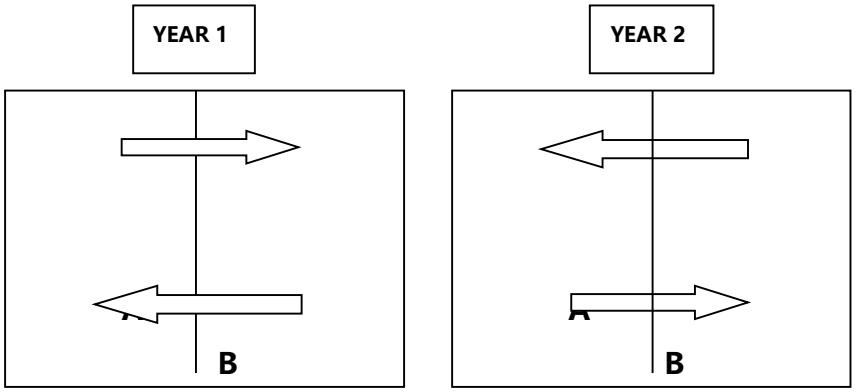

Fig. 2. Typical two (2) crops rotation in a RBC system

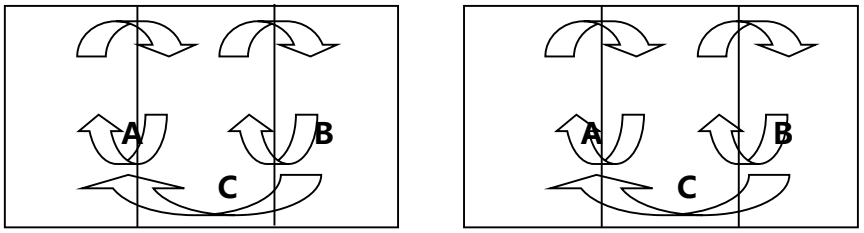

Fig. 3. Typical three (3) crops rotation in a RBC system

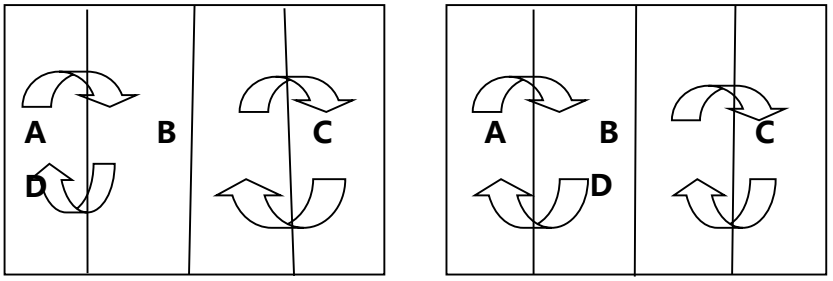

Fig. 4. Typical four (4) crops rotation in a RBC system

Key: A, B, C, D = Crops

3.2 Nutrient management

Smallholders can adopt good soil management method such as the use of mulch or a combination of fertilizers and mulch. Combined application of mulch and mineral fertilizer resulted in an improved soil chemical and physical (bulk density) qualities [6]; it also gave better rubber stem girth and cooking banana yield the test crop for the trial (Table 3)

Table 3. Rubber saplings stem girth(cm)as influenced by cropping systems, fertilizer and mulch on an acid sand soil during the first 4 years of plantation establishment

Cropping Systems	Fertilizer*	Fertilizer + Mulch#	Mulch +	Control (No fertilizer and Mulch)	Mean
1 year old Sole					
Sole Rubber	10.6	11.5	9.2	9.3	10.02
Rubber + Cadaba banana	9.6	9.9	7.3	8.4	8.8
Rubber + Bluggloe banana	7.5	9.9	7.5	5.5	8.4
Mean	9.5	10.3	8.0	7.7	
LSD (P ≤ 0.05)	CS=NS	FM=2.2	CSXFM=NS		
2 years old Sole					
Sole Rubber	17.3	19.6	15.3	17.3	16.9
Rubber + Cadaba banana	15.8	16.8	13.7	13.1	14.9
Rubber + Bluggloe banana	13.8	16.6	12.7	9.2	13.1
Mean	15.6	17.7	13.9	9.9	
LSD (P ≤ 0.05)	CS=NS	FM=3.80	CSXFM=NS		
3 years old Sole					
Sole Rubber	24.9	29.8	26.9	19.6	25.3
Rubber + Cadaba banana	27.2	40.7	27.8	16.7	28.6
Rubber + Bluggloe banana	26	38.3	24.8	15.4	26.1
Mean	26	36.3	26.5	17.2	
LSD (P ≤ 0.05)	CS = NS	FM = 8.8	CS X FM = 4.7		
4 years old Sole					
Sole Rubber	32.8	37.5	31.7	25.9	31.9
Rubber + Cadaba banana	38.6	44.6	32.1	24.3	34.9
Rubber + Bluggloe banana	31.7	40.6	30.0	2.2	31.1
Mean	34.4	40.9	31.3	24.1	
LSD (P ≤ 0.05)	CS = NS	FM = 11.8	CS X FM = 3.50		

Key: ** 31.1 Kg N/ha, 36.5KgK2O/ha,18.2 Kg P2O5/ha and 7.57 Kg MgO/ha for rubber; 138 Kg N/ha, 29Kg/ha P2O5, 95.5 Kg K2O/ha and 188.4 Kg/ha for cooking banana cultivars*

 # 75% of the fertilizer applied either to rubber or cooking banana + 5000Kg/ha of mulch + 5000Kg/ha of mulch applied yearly for 2 years
CS: Cropping systems
FM: Fertilizer and mulch
CS FM: Cropping systems and fertilizer interactions*
NS: Not significant
Source: [7]

3.3 Weed management

Studies have shown that cassava inter cropped in rubber inter rows can effectively control weeds as much as *Pueraria phaseoloides* in rubber inter row. There was no significant difference on the percentage reduction in weed density for *Pueraria cover crop*, rubber/maize/cassava (0.25x0.75/1.5x1.0m) and cassava (1.0x1.0m) intercropped with rubber. This trend was also observed in the percentage reduction in biomass of *Pueraria* cover crop, rubber/maize/cassava (0.25x0.75/1.5x1.0m) and cassava (1.0x1.0m) intercropped with rubber compared to rubber/natural vegetation (Table 4). Crops such as melon, pineapple and plantain have been shown to be effective in control of weeds in intercropped immature plantation. Smallholders can save scarce funds on herbicides and adopt simple technology, that is friendly to the environment and improve their livelihood.

Fig. 5. Effective ground cover of cassava in immature plantation

Fig. 6. Effective weed control of soils under immature rubber cultivated to melon in a rubber/cassava/melon intercrop

Table 4. Effect of rubber based cropping systems on weed density and biomass

Cropping Systems	**Cropping Density**	**Percentage reduction in weed density compared to natural vegetation**	**Biomass**	**Percentage reduction in biomass compared to natural vegetation**
	(No./m^2)	**(%)**	**(Kg/ha)**	**(%)**
Rubber + natural vegetation	13.4	0	1351	0

Rubber + Pueraria phaseoloides	0.83	92.2	238.7	82.3
Rubber + maize (0.25 x 0.75 m)	7.81	41.7	331.4	75.5
Rubber + maize (0.50 x 0.75 m)	10.2	23.9	558.2	58.7
Rubber + maize (0.60 x 0.90 m)	9.44	29.6	393.6	70.5
Rubber + cassava (1.00 x 1.0 m)	4.24	68.4	170.1	87.4
Rubber + cassava (1.00 x 1.0 m)	4.48	66.6	162	88.0
Rubber + cassava (1.00 x 1.0 m)	4.22	68.5	200.4	85.2
Rubber + maize + cassava (0.25 x 0.75/1.50 x 1.0 m)	2.8	79.1	175.1	87.0
Rubber + maize + cassava (0.50 x 0.75/1.00 x 1.0 m)	3.59	73.2	209.2	84.5
Rubber + maize + cassava (0.60 x 0.90/1.50 x 1.0 m)	4.2	68.5	208.4	84.5
LSD (0.05)	**1.4**		**152,6**	

Source: [8]

3. 4 Rubber based agroforestry system

The rubber-based agroforestry and rubber mixed farming systems was developed in RRIN to attract smallholder to rubber cultivation, which has suffered drastic decline in recent years. The system involves the maximum utilization of land, by cultivating other crops, fruit trees and mini livestock along with rubber. The system leads to early returns on investment and diversification of source of income for the farmer. It also preserves the environment thereby encouraging biodiversity. Farmers can adopt a number of cropping patterns; such as:

a) Multiple Cropping: Planting several crops within an area of land
b) Inter Cropping: Planting similar plants with different time of maturities
c) Relay Cropping: One crop giving way to another crop on the same area of land
d) Alternate Avenue Intercropping: Rotation of crop mixtures within rubber avenues.

There are also a number of crop combinations available to the smallholder rubber farmers to adopt or practice. Possible crop combinations include:
Rubber / Pineapple
Rubber / Plantain
Rubber / Cassava
Rubber / Yam / Melon / Maize
Rubber / Cassava / Melon / Maize
Rubber / Beniseed / Melon

Rubber / Maize / Cowpea
Rubber / Tree Crop
Rubber / Tree Crops / Arable
Rubber + maize + groundnut + Cassava
Rubber + maize + groundnut + yam

Fig. 7-10. Rubber/yam /pineapple; rubber/rice/maize and rubber/bitter leaf intercrop

Peripheral planting of high value fruit trees and medicinal plants in rubber plantation is recommended for smallholders' farmers in Nigeria. This rubber agroforestry not only enhances the trees scape, it helps to improve the resilience of the farmer, due to improved livelihood.

Fig. 11. Rubber/Irvingia (Bush mango) peripheral planting

Presented in Figure 12 to 14 are some examples of high value fruits (*Dennittia tripetala* (Pepper fruit), *Gambeya albida* and medicinal plants (*Moringa oleifera)* which can serve as additional income source for farmers.

Fig. 12. *Dennittia tripetala* (Pepper fruit)

Fig. 13. *Gambeya albida*

Fig. 14. *Moringa oleifera* plant and seeds

3.5. Mixed farming

After canopy closure, planting of shade tolerant crops and mini-livestock rearing has been developed under mature rubber plantation and are currently being popularized among rubber farmers in Nigeria. These systems have been found to be compatible with rubber and are capable of improving the economy of the systems. Increased economic benefits from mixed farming where crops and animals interact together [13]. [1] in a study of oil palm and goat integrated systems reported that integrating goat and oil palm has numerous economic benefits such as sustainability, environmental integrity, enhanced productivity and food security. In Rubber Research Institute of Nigeria, apiculture (Bee-keeping) is one of the integrated farming systems developed under matured rubber plantation and being disseminated to rubber farmers in Nigeria. Bee-keeping is the applied science of rearing honey bees for human benefits [9]. Some of the benefits of bee-keeping include; pollination, production of pollen grains, honey, bee wax, bee venom and royal jelly. Rabbitry and snailry are mixed farming options also recommended for smallholder rubber farmers in Nigeria as alternative source of income to rubber production and as a means of improving livelihood and resilience of the farmer.

Fig. 15-18. Rubber based mixed farming system with mini livestock (snailry, rabbitry and honeybee keeping)

3.6 Socioeconomic benefits to the rubber smallholder farmer

Smallholder farmers have the option to intercrop different crops like cassava, yam, maize, plantain, pineapple, millet, leafy and fruity vegetables that are most profitable considering their family and market needs. Table 5 highlights the possibility of farmers making positive returns on capital invested for different combination of cropping systems .

Table 5. Cost and Benefit of 1ha Rubber based agroforestry Systems

Cropping systems	**Total costs of production (₦)**	**Total derivable revenue year 1 (₦)**	**Profit margin year 1 (₦)**
Rubber + Plantain	400,000.00	500,100.00	109,100.00
Rubber +Cassava	344,000.00	544,000.00	200,000.00
Rubber +Pineapple	344,000.00	424,000.00	80,000.00

1 USD equivalent to 408 Naira.

The profitability analysis of rubber honey bee mixed farming, showed higher values of profitability index, percentage RRI and RRVC for the mixed farming compared with sole rubber production Table 6.

Table 6. Profitability Analysis of rubber honeybee mixed farming

Profitability Analysis	**Sole Rubber**	**Rubber + Honey Bee**
Profitability Index or Return on sale	0.31	0.53
Rate of Return on Investment (%RRI)	31%	53%
Rate of Return on Variable Cost (%RRVC)	150%	231%
Operating Ratio	0.61	0.41

Source: Esekhade et al. (2010)

Pictorial representations (Fig 19-21) show the produce from rubber based intercropping and mixed farming. Of utmost importance is food and fibre production from the systems, coupled with the effect on livelihood as a result of alternative income source.

Fig. 19. Cassava harvest by women in immature rubber plantation

Fig. 20. Rich harvest of plantain from rubber/plantain intercrop

Fig. 21. Packaged honeybee from rubber based mixed farming system

3.7 Strategies to build the resilience of smallholder farmers in Africa

Strategies to build the resilience of smallholders farmers lies in the abilities of the farmer to adapt to the changing circumstances of our time. Mono-cropping will definitely no longer be the norm. Diversification of income stream under a sustainable and environmentally friendly manner is recommended for the smallholder farmer. In addition to sustainability it is pivotal to build the capacity of the smallholders, by first ascertaining their skills gaps and areas of needs and training as appropriate.

4 Conclusion

The results of this studies demonstrated clearly that, it was more profitable for smallholder rubber farmers to intercrop different crops (cassava, yam, maize, plantain, pineapple, millet, leafy and fruity vegetables) and adopt rubber-mini livestock farming (Snail, rabittary and Bee keeping) to generate additional food and income for their family and market needs, thereby increasing early return on investment, improve profitability and attract more farmers especially smallholder to rubber cultivation, for a sustainable rubber production in Nigeria. To achieve this, emphasis should be placed on application of appropriate agronomic protocols, capacity building and sustained investment on research and development.

Farming in this part of the world is largely in the hands of the resource poor farmers with limited access to land and credits. Integrated farming system therefore remains the dominant farming practice recommended for smallholders to enhance their livelihood and boost their resilience in coping with current local and global challenges especially, COVID 19, climate change and insecurity.

References

1. Davendra, C. *Goat in integrated systems with oil palm: Implication for increased productivity and food security* (2010). [Available] at http://www.iga.goatworld-integrated-systems-with-oil-palm-102html
2. Esekhade, T.U., I.K. Ugwa, and E.O. Aigbekhaen. Indian Journal of Natural Rubber Research. **9**,**1:**36 – 39(1996).
3. Esekhade, T. U., & Ojiekpon, I. F. Indian Journal of Natural Rubber Research. 10: 9196(1997).
4. Esekhade, T.U. and I.K. Ugwa. MusAfrica. **14:**11 – 17(2000).
5. Esekhade, T.U., I.K. Ugwa, J.R. Orimoloye and S.O. Idoko. Journal of Sustainable Agriculture. **22**,4: 79 – 94(2003).
6. Esekhade, T. U., Okore, I. K., Ogeh, J., & Idoko, S. O. Jr. of Sustainable Agriculture and Environment. **7**:1020(2005).
7. Esekhade, T.U & Okore, I. Open Journal of Forestry. 2:65-70(2012). doi: 10.4236/ojf.2012.22009.
8. Esekhade, T.U., Ogeh J.S and H.Tijani Eniola. Journal of Agriculture anf Forestry and Fisheries. **5**,2: 42 – 49(2004).
9. FEBKAN. Federation of Beekeeping Association of Nigeria. *Nigeria Standard on National Honey*. Technical Committee Submission 2003).
10. Kay, R. O. *Farm Management, Planning, Control and Implementation*. Mc Graw Hill Book Company. London.154—156pp (1981).
11. Onuoha, R. E. and Ohaka, C.C. International Journal of Food and Agricultural Research. **3**,2 (2006).
12. Simien, A. & Penot, Eric. Journal of Sustainable Forestry. 30:247-260(2011). 10.1080/10549811.2011.530936.
13. Thelma R. Paris (2002). Crop-animal systems in Asia: Socio-economicbenefits and impacts on rural livelihoods. Agricultural systems. **71**,1-2:147 (2002). [Available] at http://sciencedirect.com/science?-os=article
14. Zainol, E.A., A.W. Mahmud and M.N. Sudin. Natural Rubber Research. **8920**:124 – 136(1993).