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Socio-Economic Factors Affecting the Income of Small-scale Agroforestry Farms in Hill Country Areas in Yemen: A Comparison of OLS and WLS Determinants

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Yemen is a less-developed country in the Arabian Peninsula, with only 3% arable land. An agroforestry land-use system has been practiced traditionally by small-scale farmers, but is associated with low productivity and income. A study has been undertaken to determine the socio-economic attributes of farmers that influence the financial performance of agroforestry and non-agroforestry farms in the Bura'a Mountain region. A survey was conducted of 150 farmers involved in both agroforestry and non-agroforestry. Both OLS and WLS regression were applied, and coefficients compared in terms of consistency and goodness of fit. Incomes of farmers were found to be influenced by education, area of land, livestock holding, family size, and whether coffee is grown, but not farmer's age. The WLS method produced efficient and consistent results, whereas OLS regression was affected by the heteroscedasticity. The findings of the study indicate that the farmers of the study area are in need of financial and technical support from government to increase their income. Infrastructural development and public intervention in developing farmers' technical know-how could enhance production and ensure the optimum use of land as well as soil and water conservation.

Keywords: Bura'a Mountain region, heteroscedasticity, WLS regression analysis, income determinants, highland agroforestry

INTRODUCTION

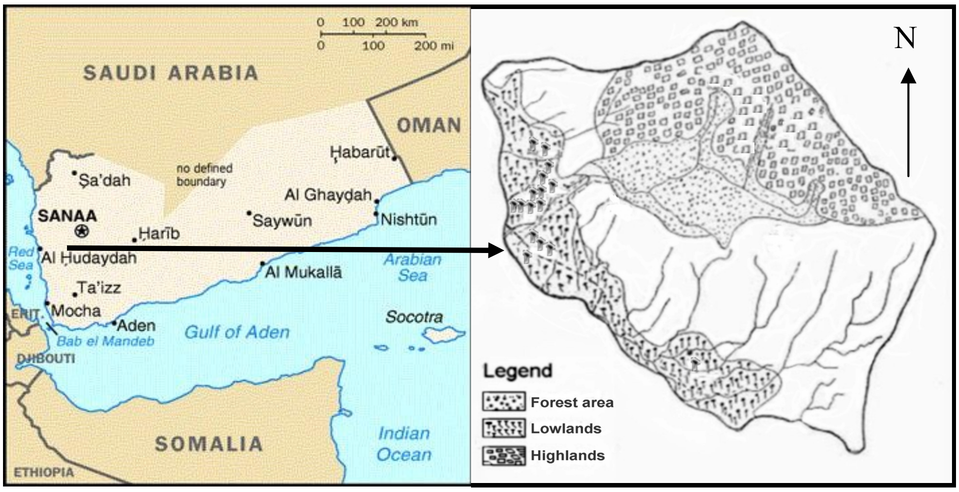
Agroforestry (AF) is a widely practiced land use for smallholders in the tropics and subtropics. An understanding of the factors affecting AF farm income allows policy-makers to devise measures to support their livelihood and encourage sustainable land use. A substantial body of literature indicates that smallholder AF farm income in the tropics and sub-tropics is related to the socio-economic attributes of farmers, as well as farming technology, cropping patterns and land quality. Sadeghi *et al.* (2001) regressed farm income on socio-economic characteristics of Iranian farmers, and found that area of cropland, fruit land and livestock holding significantly affects income. Phandanouvong (1998) found that the income of Lao AF farmers was positively related to farm size, and farmer education level and age.

A study of the socio-economic impact of a participatory AF program in Bangladesh revealed that the involvement of landless people in AF in degraded forest increased the economic return of government and participants from the land as well as economic and ecological sustainability (Safa *et al*. 2002, Safa 2004). It also showed that the socio-economic attributes of farmers, including age, family size, education, farming experience and land size are strongly related to farming success. Neupane and Thapa (2001) found that the agricultural system with AF was more profitable than the conventional subsistence farming system in the Middle Hills, Nepal. They also found that the introduction of multi-purpose trees (MPTs) could further enhance the profitability of the AF system. Karki (2001) conducted a study on the contribution of AF to farm household income and community forestry management of 111 households in India, and found silvo-pastoral interaction increased household income significantly. Peeters *et al*. (2003) reported that coffee production in Mexico was higher under an AF system than mono-cropping, though the production of timber and other secondary produce was reduced.

Studies on variables affecting AF farm income have mostly considered the effect of socio-economic attributes without considering contemporary non-agroforestry (NAF) practices. Socio-economic attributes such as size of landholding, livestock numbers, education level and farmers' age were found to influence positively the income from farming activities, though with some exceptions. However, the relationships of these factors with farm income under different land-use options have not been adequately investigated in Yemen. Moreover, because socio-economic attributes vary geographically, the relationships may also vary spatially. This study has been designed to determine the influence of farmer household socio-economic attributes on income from AF and NAF systems, in both the highlands and lowlands of the Bura'a Mountain region in Yemen. First, the socio-economic and political structure of Yemen is described. The research method is then outlined, and the survey results and statistical analysis reported. Concluding comments follow.

THE RESEARCH SETTING IN NORTHERN YEMEN

Yemen is in the Middle East lying between about 13'00^0 and 19'00^0 north latitude, bordering the Arabian Sea, Gulf of Aden, Red Sea, Oman and Saudi Arabia (Greenwich Mean Time 2004). The total land area of Yemen is 527,970 km^2 including the islands of Perim and Socotra. The population was estimated at 19.2 M in 2003 (World Bank 2004). The highest elevation is 3760 m above sea level at Jabal-an-Nabi Shu'ayb. Most of the land is desert, with a hot and humid climate along the west coast, extraordinarily hot, dry and harsh desert in the eastern part, and a temperate climate with seasonal monsoons in the western hilly area. Figure 1 illustrates the location of Yemen and the Bura'a Mountain region. The Bura'a region is situated on the slopes of the Tihama foothills and surrounded by Almarawa'h, Raymah, Alsokhnah, and Bajel districts. Bura'a is 50 km east of Al-Hudaydah city that is 178.9 km north-west from Tai'zz. The study area includes the Wadi Rigaf watershed and a large part of Wadi Al-Aswad watershed.



Source: Greenwich Mean Time (2004).

Figure 1. Map of Yemen (left) and the Bura'a Mountain region (right)

In early times, Yemen was one of the historical civilisations in the Near East. Between the 12th century BC and the 6th century AD, it was a part of the Minaean, Sabaean and Himyarite Kingdoms. It then came under Ethiopian and Persian rule. In the 7th century, Islamic caliphs began to gain control over the old Yemen. After this caliphate broke up, North Yemen came under control of Imams of various dynasties,[1] predominantly of the Zaidi sect who established a theocratic political structure that survived until modern times. Subsequently, Egyptian Sunni caliphs occupied much of North Yemen throughout the 11th century. By the 16th century and again in the 19th century, North Yemen became part of Ottoman Empire, from which it gained independence in 1918. South Yemen on the other hand came under British command at the end of Ottoman Empire because of its failure to remain integrated with the north and the change of global politics at the time WW 119. The British withdrew in 1970, and the two countries became united as the republic of Yemen on May 22, 1990.

At present, Yemen is the only democratic country on the Arabian Peninsula and faces serious political, social and economic challenges. Various issues – including tribalism, traditional cultural structure and unstable economic systems – severely constrain development. Tribalism is the greatest impediment due to the social power of tribes as the primary social unit. On unification, Yemen introduced a strategy based on three concepts – unity, pluralism and economic structural adjustment. However, this strategy has had limited success; several factors, including socio-economic and political instability, have hindered genuine political and economic reform.

[1] *Imam* is a religious term in Arabic that is used for the grandsons of Muslim's Prophet Muhammad and subsequent lineal descendents considered to be his successors.

The Economy of Yemen

Yemen's economy is characterised by weak national integration between north and south and also within the territory of each (Nonneman 2004). Distribution systems of the economy are antiquated. In many places there are three functioning economies – a subsistence economy, a market economy with external linkages including foreign trade, and 'black-market' (smuggling) economy. Implementation of national economic policies is limited, which has resulted in unstable economic growth. Severe socio-economic problems arise from the relatively large population and a population growth rate that is amongst the highest in the developing world. This places pressure on employment generation, the public service, and natural resources.

In 2003, the GDP of Yemen was estimated at $4.9 billion, with per capita income of about US$510 (World Bank 2004). An estimated 42% of the total population is under the national poverty line, defined by the Cost of Basic Need method (Head Count Ratio) (World Bank 2004).[2] About 75% of the population lives in rural areas, where poverty incidence is highest. National statistics indicate the prevailing socio-economic conditions: Life expectancy at birth of 57 years; infant mortality of 83 per 1000 live births; 46% of children younger than 5 years suffering malnutrition; only 69% of the population with access to clean water; and 50% of the population older than 14 years illiterate (World Bank 2004). About 1.8–2 M people work overseas,[3] export of labour mitigating the national unemployment problem to some extent (World Bank 2004).[4] Due to the Yemeni government's stance against the allied operation to evict Iraq from Kuwait during the first Gulf War, Saudi Arabia expelled about 800,000 Yemeni visiting workers in 1990-91, which halved the inflow of remittances and had severe economic effects.

North Yemen commenced exporting oil in 1987. Oil exploration in the border zone between North and South was one of the factors in leading to closer co-operation and eventual unification. National gas reserves are estimated at 5-20 trillion cubic feet, although development of this resource will be difficult and expensive. In 1988, the port of Eden was declared a 'free zone' to liberate trade and business. However, the first Gulf War and subsequent fear of instability dampened investor confidence. Nevertheless, the industrial sector of the economy has comparatively greater stability in terms of growth than other sectors.

The agricultural sector employs about 60% of the national labour force, and contributes 22.6% of GDP (Nonneman 2004). Nationally, about 2.9% (1.7 M ha) of the land area is suitable for cultivation, and about 2% (1.1 M ha) is actually cultivated (MAI and FAO 2000). The arable land is divided into 1.115 M holdings, of which an estimated 69% are small farms (less than 2 ha), and 29% are medium sized (2 to 5 ha). Traditional AF as cropland agroforestry, terrace-land agroforestry and home garden agroforestry is found in the Bura'a Mountain study area. This land-use system is highly important to the people in terms of food security, income generation and environmental protection. In the northern highlands, terrace-based

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[2] Cost of Basic Need (CBN) is method to measure the poverty indices. It identifies the level needed by the people to afford the basic necessities to survive.

[3] This is a common estimate of the population that remains almost same in the recent years for labour force working abroad.

[4] This is a common estimate of the labour force working abroad and has remained almost the same in recent years.

agriculture relies on seasonal rainfall and irrigation. In the south, agriculture is concentrated in the Wadi Hadhramaut. Officially, the country's main crops are sorghum and millet. However, one of the most commonly grown crops, Qat, does not appear in official statistics because it is not included in the group of staple foods.[5] There is much dispute over the role of Qat in rural livelihoods (Alsanoy 2004). Qat cultivation has kept many terraces maintained that would otherwise have been left unattended. Indirectly the cultivation of Qat ensures soil and water conservation by using the terrace lands. However, Qat production uses substantial labour and land, but makes no contribution to national nutrition levels or export earnings.

Agricultural activities generate the subsistence income of rural Yemenis. However, this sector is not well organised or able to support aspirations for increasing living standards. The Yemeni agricultural sector faces a number of constraints, including severe erosion of the mountain terraces and over-use of the limited water resources. Alsanoy (2004) reported the socio-economic condition of Yemeni farmers deteriorating, with low productivity and income levels, and increasing levels of poverty, and soil and water degradation. There is no appropriate modern AF technology followed by the farmers. Lack of financial investment in farming activities exacerbates the failure of smallholders to maintain their standard of living, leading to extreme poverty. Farmers are migrating to neighbouring countries as well as Yemeni cities for supplementary incomes to support their families. This further contributes to the lack of terrace maintenance and degradation of soil and other natural resources (Al-Hebshi *et al*. 2004).

Agroforestry Systems in Yemen and the Bura'a Mountain Region

Most arable land is in Northern Yemen where the study area, the Bura'a Mountain region, is located. Traditionally, Yemeni farmers have practiced AF in the form of terrace cultivation. Nahal (1989) classified nine major types of AF systems in the southern and eastern provinces of Yemen according to the main functions and products. These systems include indigenous multipurpose trees and shrubs that contribute to environmental protection, food security and desertification control. Several traditional AF systems integrating woody species with crop cultivation or animal rearing exist in the various ecological zones of Yemen. The indigenous species most commonly used in these traditional AF systems are: *Acacia negrii, A. tortilis, Cordia abyssinica, Dobera glavra, Ficus vasta, Tamarix nilotica and Zizyphus spina-christi*. Recently, farmers have introduced fast growing exotic species for shelterbelts and in some regions – including Tihama and Maareb – to stabilise sand dunes. The most commonly used exotic species are *Azadirachta indica, Cononcarpus lancifolius, Melia azedaracht, Parkinsonia aculeata, Prosopis chiliensis and Prosopis juliflora* (Sabra and Walter 2003). Several AF systems which are suitable under conditions of water stress and high temperature are traditionally practised in the coastal environment of Yemen.

Herzog (1994) and FAO (1997) classified the Bura'a area into two regions according to altitude above sea level. One is the mountainous highland – a fertile

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[5] Qat *(Qatea edulis)* is shrub, the tender leaves of which are chewed by most Yemenis as a mild stimulant, like the betel leaf in India.

region suitable for plantations of *Coffea arabica* and *Qatea edulis*. The other region is the valley region, which is considered the best for AF systems due to the availability of water and high soil fertility. The terraces of Bura'a are mainly over 800 m above sea level, and coffee and Qat are grown at an altitude of 1000-2000 m. Other crops include sorghum, millet and maize.

Some of the AF practices in the Bura'a region include: Field crops and date palms – *Lotus jujub* and *Zizyphus spina-christi*: Field crops and dispersed trees – *Zizyphus Christi, Mangifera indica and Azadirachta indica*: Field crops – *Acacia tortils*, *Acacia ehrenbergianai* and *Prosopis juliflor*; and Tropical fruit – *Ziziphus spina-christi* (Nahal 1989). Livestock rearing is a secondary livelihood activity in the Bura'a Mountain region. In some places selling firewood is an economic activity, along with small-scale trading of groceries and stationery (CSO 1996).

RESEARCH METHOD

Eleven villages in the Bura'a Mountain region were selected for the study, namely Haz-Alshamah, Kabba and Alshat, Al-Sabt, Al-Koa'ad and Aldar, Deer Orrag, Deer Al-Tobain, Maktarah, Kamat Bani Bagi, Al-Magareb, Sanab and Al-Kahib. The main criteria to select study villages were geographic dispersion in lowlands and highlands, low coffee production as an AF component, declining socio-economic condition of farmers, intensive traditional practice of AF, and variations in land-use pattern according to altitude. The sampling frame of the study was the lists of farm households practicing AF, available from the local agricultural offices for each village and, for NAF farmers, lists collected from local information offices.

A structured questionnaire was developed and tested, and 118 AF farm households and 32 NAF households were selected by simple random sampling. The heads of households were interviewed over the period July to September 2002. Secondary information including cropping pattern of the study area and infrastructure facilities was obtained from the Directorate of Forestry and Desertification Control (DGFDC), FAO and the Central Statistical Organisation (CSO) of Yemen. Some unstructured interviews were conducted with the heads of the villages to verify survey information. The sampling fraction of the population was 0.64 and 0.85 for the AF and NAF farmers respectively. The sampling procedure was not proportionate because of difficulty arranging interviews in the hilly areas. The major research challenges, especially in upland areas, were limited accessibility and the lack of effective communication channels. In rural Yemen, animals, and in particular, donkeys, are the main mode of transport. Researchers and enumerators sometimes reached a household but could not find the household head as he was out or working in the field. Repeat visits were made and the respondents were sometimes found. The absence of accommodation facilities for the researchers and enumerators further hampered survey work in upland areas.

Model Formulation

A population model has been developed in which farm income (expressed in Yemeni Ryal) is hypothesised to depend on seven explanatory variables, namely:

a) family size (FS) – the total number of members in respondent's household, including adults and children;
b) age (AG) – the age of the respondent, normally household head, at the time of interview (years);
c) land size (LS) – the arable area of AF and NAF (ha);
d) number of animals (NA) – the number of sheep, cattle (typically dairy cows) and camels;
e) education level (EDDM) – dummy regressor, zero if the respondent is illiterate and one if the respondent had attended at least four years of primary schooling;
f) coffee production (CFDM) – dummy regressor, one if the farmer grows coffee and zero otherwise; and
g) AF system (ANDM) – dummy regressor, one if the farmer practices AF and zero otherwise.

A priori, it was expected that the coefficient indicating the nature of the relationships between households' income and socio-economic attributes would be negative for age and positive for the other six explanatory variables. Initial regression runs revealed heteroscedasticity (H.S.), with the residual variance increasing as income level land size and age increased. This violates the homoscedastic variance assumption of the ordinary least squares (OLS) method. The heteroscedastic error variance associated with the land size and age variable appears to be due to farmers with relatively large land areas having greater crop diversity and age of the owner. To remedy this problem, the weighted least squares (WLS) procedure was applied. To achieve approximate normality and homogeneity of error term, the variables age, family size, land size and number of animal holdings were transformed by taking logarithms (following Gujrati 2003). In order to reach the homogeneity assumption of Classical Linear Regression analysis, age and land size variable were squared and added into the model. The Jarque-Bera/Salmon-Keifer test was used to examine the normality of the error term while the Breusch-Pagun test was used to detect the heteroscedasticity problem. In addition, the analysis included using the heteroscedastic standard error of the coefficient. A graphical analysis was also carried out for each model to ensure the removal of heteroscedasticity problems, as presented in Appendix A. Both OLS and WLS estimates are reported. While the latter are the more reliable, it is felt that the comparison of findings provides insights into the effect of failure to recognise heteroscedasticity in survey data.

Two further population models were defined, to compare the relationship between income and socio-economic variables for highland (coffee producer) and lowland (non-coffee producer) farms, and for highland AF versus lowland AF farms. For the former, a dummy variable is again used to represent AF and NAF land use. Coffee is a common component of highland AF farms, being favoured by the relatively low temperature at high altitude, but is uncommon in lowland AF. Hence the dummy variable for coffee was deleted from these models. For the highland-lowland AF comparison, the dummy variable for both coffee and AF-NAF were eliminated.

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Sampled Farmers

Table 1 reports the sample means of socio-economic variables of Bura'a farmers overall, highland farmers, lowland farmers, highland AF farmers and lowland AF farmers. The results of *t*-tests for the difference between means of socio-economic variables for all highland and lowland farmers and between highland AF and lowland AF farmers are also listed. Among the five groups, the mean income of highland AF is higher than all others followed by all highland farmers. The mean family size and age of the household head is highest for highland farms. Lowland farmer groups had higher average education levels than highlanders. This may suggest that either lowland farmers require a higher education level to compete in the job market to complement their farm income or that education is more accessible for the lowland farmers. Mean land size of lowland AF is higher than other groups followed by lowland farmers. The lowland farms have higher livestock numbers than highland farms. Three variables differ significantly between highland and lowland farmers, namely family size, land size and livestock holding. Between highland and lowland AF, land size and livestock holding differ significantly at the 1% level. The results reveal variations in land size and livestock holding that may have crucial implication for farm income. Table 2 reports the statistical difference in means of the socio-economic variables between AF and NAF farms. The income, land size and number of livestock are found to be significantly higher for AF farms than for NAF farms.

Table 1. Mean levels of socio-demographic attributes of the various farmer groups

Variable	Overall mean (n=150)	Highland (n=82)	Lowland (n=68)	t-value	Highland AF (n=61)	Lowland AF (n=57)	t-value
Farm income (YR)	306,403 (195,665)	321,662 (213,339)	288,002 (171,721)	1.049	367,932 (219,831)	32,1485 (166,524)	1.287
Family size (no.)	9 (3.17)	10 (3.37)	8 (2.82)	2.167*	9 (3.44)	8 (2.95)	1.673
Age (years)	49.4 (12.86)	50.4 (1.10)	47.1 (14.38)	1.571	50.8 (12.07)	47.9 (14.37)	1.164
Years of schooling (years)	2 (4.01)	2 (3.75)	3 (4.34)	-0.858	2 (3.84)	3 (4.38)	-0.433
Land size (ha)	2.47 (3.02)	0.73 (0.96)	4.57 (3.32)	-9.969**	0.83 (1.09)	5.08 (3.36)	-9.350**
Livestock and poultry (no.)	22 (20.28)	11 (9.44)	36 (21.73)	-9.247*	11 (10.22)	37 (22.94)	-8.025**

Figures in parentheses are standard errors. *Significant at 5% level; **: significant at 1% level.

Sources of Household Income

Figure 2 indicates mean incomes (n=150) of AF and NAF farms by income source. The bars represent the standard errors of the means. The sources of AF income include annual crops, particularly sorghum, maize, millet, and ginger. Income from ginger is relatively low compared with other annual crops. Perennial crops – particularly coffee and Qat – led to relatively high AF income. Timber and non-forest timber products (NFTPs) including fuel wood, charcoal, fruits and fodder, are also important sources of AF income. Livestock are a common component of the AF farms of the study area, the average income from livestock under AF being 78,900YR, compared with 38,280YR from NAF farms.

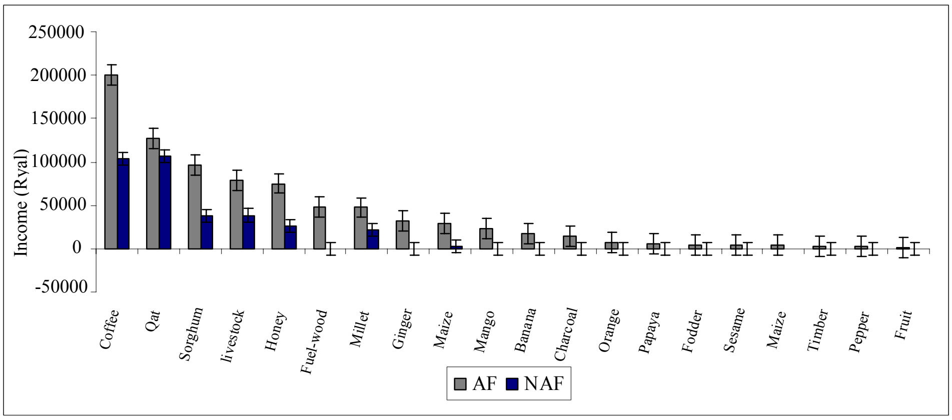

Figure 2. Mean income from AF and NAF systems by income source

Table 2. Statistical differences in means of socio-economic variables between AF and NAF farms (n=150)

Variable	AF		NAF		t-value
Income (YR)	345,496	(18,086)	162,247	(18,597)	5.07**
Family size (no.)	8.93	(0.30)	9.34	(0.52)	- 0.65
Age (years)	49.45	(1.22)	46.97	(1.99)	0.97
Land size (ha)	2.88	(0.29)	0.95	(0.19)	3.32**
Animals (no.)	23.97	(2.01)	16.69	(2.11)	1.82
Education (years)	2.58	(0.38)	1.84	(0.65)	0.93

Figures in parentheses are standard errors. ** significant at 1% level.

Regression Analysis of Overall Farm Types

The results of the OLS and WLS regressions for all farm types are presented in Table 3. The diagnostics reveal that the non-linear model (WLS) has substantially greater explanatory power than the linear (OLS) model, in terms of R^2 value. The estimated OLS coefficients for family size, land size, livestock holding and education level, coffee dummy, education dummy and AF dummy, but not age, are statistically significant. The WLS coefficients were similarly significant except for the education dummy variable. All significant coefficients have the expected signs.

The non-significance of the age of household head variable suggests that the land ownership pattern in Bura'a is independent of age. In some cases, young farmers were found to own a large land holding which led to substantial income regardless of age. Land size and livestock holding are significantly positively related to farmers' income. Coffee production and AF is found to contribute greatly to farm income level. Farmers with at least four years of schooling have higher farm incomes than illiterate farmers.

Table 3. OLS and WLS determinants of farmers' income across all farm types (n=150)

Ordinary Least Square (OLS)				Weighted Least Square (WLS)			
Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value	Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]
Constant	-145,593*	-2.19 (66,618) [0.029]	-2.00 (72,670) [0.045]	Constant	10.15**	8.49 (1.20) [0.000]	9.96 (1.02) [0.000]
AG	-819	-0.78 (1055) [0.437]	-0.84 (979) [0.403]	LOGAG	0.05	0.15 (0.36) [0.882]	0.18 (0.30) [0.858]
FS	11,981**	3.06 (3,920) [0.002]	3.09 (3,882) [0.002]	LOGFS	0.24**	3.13 (0.08) [0.002]	3.78 (0.06) [0.0002]
LS	28,827**	5.24 (5,503) [0.000]	4.93 (5,852) [0.000]	LOGLS	0.44**	9.12 (0.05) [0.000]	7.89 (0.06) [0.000]
NA	2,807**	3.65 (770) [0.000]	3.29 (853) [0.001]	LOGNA	0.17**	4.62 (0.04) [0.000]	3.80 (0.04) [0.000]
ANDM	137,126**	4.55 (30,163) [0.000]	5.87 (23,369) [0.000]	ANDM	0.59**	8.12 (0.07) [0.000]	7.65 (0.08) [0.000]
EDDM	68,299**	2.46 (27,762) [0.014]	2.20 (31,013) [0.028]	EDDM	0.07	1.02 (0.07) [0.308]	1.02 (0.07) [0.307]
CFDM	218,051**	6.46 (33,757) [0.000]	5.59 (39,014) [0.000]	CFDM	1.15**	11.15 (0.10) [0.000]	9.37 (0.12) [0.000]
				AG^2	-0.00002	-0.22 (0.00007) [0.828]	-0.27 (0.00006) [0.789]
				LS^2	-0.00077	-0.65 (0.001) [0.516]	-0.60 (0.00) [0.550]
Adjusted R^2			0.46	Adjusted R^2			0.70
F (7, 142)			19.49 [0.000]	F (9, 140)			40.46 [0.000]
Jarque-Bera/Salmon-Kiefer (normality test)			202.59 [0.000]	Jarque-Bera/Salmon-Kiefer (normality test)			1.06 [0.589]
Breusch-Pagan (heteroscedasaticity test)			67.19 [0.000]	Breusch-Pagan (heteroscedasaticity test)			16.42 [0.059]

* Significant at 5% level; ** Significant at 1% level.

Regression Analysis for Highland versus Lowland Farms

In separate regressions for highland and lowland farmers, OLS produced lower R^2 and F values than WLS (Table 4).

Table 4. OLS and WLS determinants of highland farmers (coffee producers, n=82)

Ordinary Least Square (OLS)				Weighted Least Square (WLS)			
Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value	Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]
Constant	95,601	0.89 (107,254) [0.373]	0.68 (14,075) [0.497]	Constant	13.83**	6.34 (2.18) [0.000]	6.55 (2.11) [0.000]
AG	-2,465	-1.32 (1,867) [0.187]	-1.22 (2,015) [0.221]	LOGAG	-0.57	-0.90 (0.64) [0.371]	-0.95 (0.61) [0.342]
FS	13,893**	2.51 (5,530) [0.012]	2.81 (4,951) [0.005]	LOGFS	0.29**	2.96 (0.10) [0.003]	4.17 (0.07) [0.000]
LS	0,0770**	4.86 (20,718) [0.000]	1.80 (55,930) [0.07159]	LOGLS	0.672**	9.12 (0.07) [0.000]	6.38 (0.105) [0.000]
NA	2,807	1.44 (1,952) [0.150]	1.04 (2,698) [0.298]	LOGLN	0.11**	2.51 (0.04) [0.012]	2.26 (0.05) [0.024]
ANDM	146,494**	3.52 (41,636) [0.000]	4.82 (30,371) [0.000]	ANDM	0.56**	6.18 (0.09) [0.000]	5.65 (0.10) [0.000]
EDDM	11,770	0.25 (46,859) [0.802]	0.20 (58,689) [0.841]	EDDM	-0.05	-0.47 (0.10) [0.641]	-0.43 (0.11) [0.668]
				AG^2	0.00**	0.42 (0.00012) [0.675]	0.52 (0.00010) [0.603]
				LS^2	-0.03**	-3.53 (0.01) [0.000]	-4.14 (0.01) [0.000]
Adjusted R^2			0.45	Adjusted R^2			0.72
F (6, 75)			11.96 [0.000]	F (8, 73)			27.53 [0.000]
Jarque-Bera/Salmon-Kiefer (normality test)			31.07 [0.000]	Jarque-Bera/Salmon-Kiefer (normality test)			1.73 [0.422]
Breusch-Pagan (heteroscedasaticity test)			86.66 [0.000]	Breusch-Pagan (heteroscedasaticity test)			5.47 [0.707]

** Significant at 1% level.

Comparing Tables 4 and 5, both regression methods produced higher R^2 and F values for lowland than highland farms (Table 5). Family size, land size, livestock holdings and the AF dummy are found to be significant in the WLS model for highland farms. For lowland farms, land size, livestock holdings, AF dummy and ED dummy are significant in the WLS model. In contrast with the previous regression of farms overall, the education dummy is not significant for highland farms whereas it is for lowland farms. Since coffee production is a common activity on all highland farms, it appears that growing coffee is not related to education level. But in the case of lowland farms the education dummy indicates that schooling is positively related to income. This may be because the presence of educational infrastructure and the level of farm income affect the interest in acquiring education for the poorer lowland farmers. The significant coefficients for the highland farms are similar to those of the regression of farmer income generally.

Table 5. OLS and WLS determinants of lowland farmers (non-coffee producers, n=68)

Ordinary Least Square (OLS)				Weighted Least Square (WLS)			
Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]	Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]
Constant	-90,461	-1.473 (61,420) [0.140]	-1.639 (55,201) [0.101]	Constant	8.03**	6.72 (1.20) [0.000]	7.14 (1.12) [0.000]
AG	191	0.20 (948) [0.840]	0.25 (777) [0.805]	LOGAG	0.65	1.74 (0.37) [0.082]	1.94 (0.33) [0.053]
FS	5,818	1.30 (4,490) [0.195]	1.30 (4,463) [0.192]	LOGFS	0.08	0.77 (0.10) [0.444]	0.93 (0.08) [0.352]
LS	24,541**	5.90 (4,157) [0.000]	4.31 (5,699) [0.000]	LOGLS	0.30**	4.30 (0.07) [0.000]	4.51 (0.07) [0.000]
NA	2,883**	4.84 (595) [0.000]	3.20 (901) [0.001]	LOGNA	0.30**	4.94 (0.06) [0.000]	4.26 (0.07) [0.000]
ANDM	101,933**	2.87 (35,530) [0.004]	4.47 (2,282) [0.000]	ANDM	0.64**	6.30 (0.10) [0.000]	6.31 (0.10) [0.000]
EDDM	55,310*	2.02 (27,371) [0.043]	1.88 (29,437) [0.060]	EDDM	0.16*	2.21 (0.07) [0.027]	2.15 (0.08) [0.031]
				AG^2	-0.00012	-1.63 (0.00007) [0.104]	-1.91 (0.00006) [0.056]
				LS^2	0.00113	0.93 (0.00121) [0.351]	0.93 (0.00122) [0.353]
Adjusted R^2			0.67	Adjusted R^2			0.79
F (6, 61)			23.29 [0.000]	F (8, 59)			32.40 [0.000]
Jarque-Bera/Salmon-Kiefer (normality test)			83.11 [0.000]	Jarque-Bera/Salmon-Kiefer (normality test)			0.67 [0.716]
Breusch-Pagan (heteroscedasaticity test)			83.03 [0.000]	Breusch-Pagan (heteroscedasaticity test)			3.07 [0.930]

* Significant at 5% level; ** Significant at 1% level.

Regression Analysis for Highland and Lowland Agroforestry Farms

Table 6 reports results of the income model for highland AF farms. The OLS procedure has again produced lower R^2 and F values than WLS, and in one case (livestock holdings on highland AF farms) has produced a significant result where OLS failed to do so. Family size, land size and livestock holding are significant in the WLS model (highland farms). Table 7 reports the results for lowland AF farms. The WLS model is again a better fit in terms of adjusted R^2 and F values, although the difference is not great. Land size and livestock holding is positively significantly related to income of lowland AF farms.

Table 6. OLS and WLS determinants of highland AF farms (n=61)

Ordinary Least Square (OLS)				Weighted Least Square (WLS)			
Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]	Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]
Constant	252,829	1.90 (132,831.90) [0.057]	1.42 (178,741.17) [0.157]	Constant	16.50**	7.88 (2.09) [0.000]	8.37 (1.97) [0.000]
AG	-2,758	-1.18 (2,348.09) [0.240]	-1.08 (2,553.43) [0.280]	LOGAG	-1.20	-1.94 (0.62) [0.053]	-2.10 (0.57) [0.036]
FS	13,962*	2.01 (6,954.34) [0.045]	2.61 (5,349.65) [0.009]	LOGFS	0.26**	2.79 (0.09) [0.005]	4.01 (0.07) [0.000]
LS	96,043**	4.09 (2,3494.84) [0.000]	1.72 (55,833.96) [0.09]	LOGLS	0.57**	7.982 (0.07) [0.000]	6.740 (0.08) [0.000]
NA	3,648	1.57 (2,322.64) [0.116]	1.14 (3,206.06) [0.26]	LOGNA	0.12*	2.497 (0.05) [0.013]	2.323 (0.05) [0.020]
EDDM	5,766	0.09 (61,220.04) [0.925]	0.077 (75,330.75) [0.939]	EDDM	-0.07	-0.66 (0.11) [0.509]	-0.60 (0.12) [0.546]
				AG2	0.00017	1.39 (0.00012) [0.164]	1.67 (0.00010) [0.094]
				LS2	-0.03**	-2.792 (0.00895) [0.005]	-3.43 (0.00730) [0.001]
Adjusted R^2			0.37	Adjusted R^2			0.69
F (5, 55)			7.97 [0.000]	F (7, 53)			19.86 [0.000]
Jarque-Bera/Salmon-Kiefer (normality test)			13.20 [0.001]	Jarque-Bera/Salmon-Kiefer (normality test)			1.481146 [0.477]
Breusch-Pagan (heteroscedasaticity test)			50.09 [0.000]	Breusch-Pagan (heteroscedasaticity test)			4.513194 [0.719]

* Significant at 5% level; ** Significant at 1% level.

Table 7. OLS and WLS determinants of lowland agroforestry farms (n=57)

Ordinary Least Square (OLS)				Weighted Least Square (WLS)			
Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]	Variable	Estimated coefficient	t-value (S.E.) [p-value]	H.S. t-value (H.S. S.E.) [H.S. p-value]
Constant	-5,452	-0.08	-0.08	Constant	9.29**	7.17	7.26
		(71,145)	(69,209)			(1.30)	(1.28)
		[0.939]	[0.937]			[0.000]	[0.000]
AG	423	0.39	0.50	LOGAG	0.50	1.24	1.32
		(1,087)	(844)			(0.40)	(0.37)
		[0.697]	[0.616]			[0.214]	[0.186]
FS	5,654	1.13	1.18	LOGFS	0.05	0.51	0.68
		(4,989)	(4,812)			(0.11)	(0.08)
		[0.257]	[0.240]			[0.614]	[0.497]
LS	24,277**	5.38	4.20	LOGLS	0.27**	3.30	3.67
		(4,513)	(5,784)			(0.08)	(0.07)
		[0.000]	[0.000]			[0.001]	[0.000]
NA	3,015**	4.61	3.13	LOGNA	0.30**	4.56	3.90
		(654)	(962)			(0.06)	(0.08)
		[0.000]	[0.002]			[0.000]	[0.000]
EDDM	65,618*	2.06	1.92	EDDM	0.15	1.89	1.83
		(31,904)	(34,116)			(0.08)	(0.08)
		[0.040]	[0.054]			[0.059]	[0.067]
				AG2	-	-1.16	-1.36
					0.00009	(0.00008)	(0.00007)
						[0.246]	[0.173]
				LS2	0.00148	1.11	1.08
						(0.00134)	(0.00137)
						[0.268]	[0.279]

Adjusted R^2	0.59	Adjusted R^2	0.62
F (5, 51)	17.19	F (7, 49)	14.01
	[0.000]		[0.000]
Jarque-Bera/Salmon-Kiefer	41.11	Jarque-Bera/Salmon-Kiefer	0.24
(normality test)	[0.000]	(normality test)	[0.886]
Breusch-Pagan	62.13	Breusch-Pagan	3.54
(heteroscedasaticity test)	[0.000]	(heteroscedasaticity test)	[0.831]

* Significant at 5% level; ** Significant at 1% level.

CONCLUDING COMMENTS

Not surprisingly, heteroscedasticity was found to be present in cross-section data relating farm income to a number of farm and household variables. As well as having greater statistical validity, WLS consistently outperforms OLS in terms of goodness of fit. Net income on agroforestry farms is generally higher than on non-agroforestry farms. Land area and number of animals consistently influence farm income, while level of education is a significant explanatory variable on lowland farms only.

The study findings have a number of policy implications. The AF farming system has a significant positive effect on the income of small-scale farms of the Bura'a Mountain area. The average income of AF farms is higher than that from NAF farms. The average income from cereal crops (mainly sorghum, millet and maize), coffee and Qat is higher for AF practices than NAF because of interaction between different components. The findings provide guidance on appropriate socio-economic scenarios for policy makers to design the necessary support measures to increase farm income as well as livelihood in the study areas. Thus, it is to be recommended that input support such fertiliser, irrigation facilities, and training could be provided to farmers to increase farm income and enhance their livelihood. A training program could focus on farmers' skills in modern techniques as well as other capacity-building actions. In that natural calamities (particularly drought) cause low production, there is a case for closer integration of farming practices, incorporating apiculture and other drought resistant Multi-purpose Trees (into the AF production system. Since income is positively related to livestock holdings, greater attention and technical support for livestock enterprises within the AF system is to be recommended. Proper technical support could encourage and assist small-scale livestock farming by female members of households.

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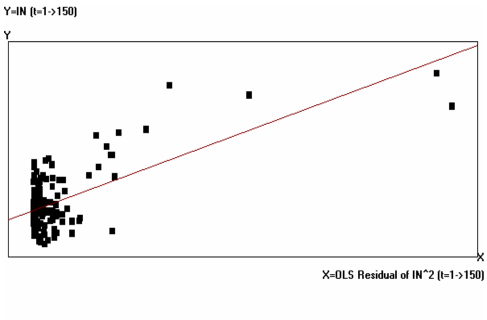
Appendix A

Graphical presentation of removal of non-homogenous variance: Scatter plot of dependent variable Y and squared residuals of each regression analysis



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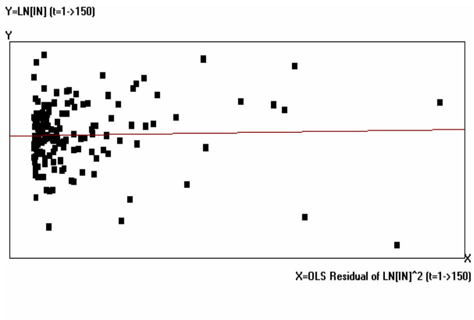

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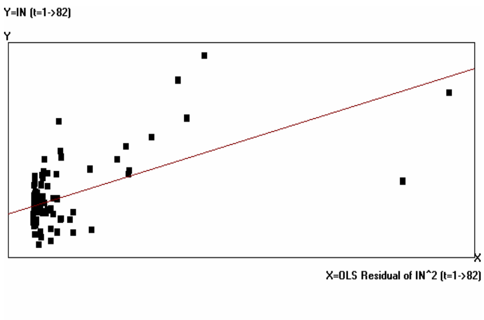

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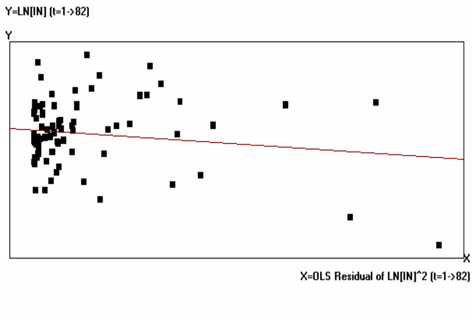

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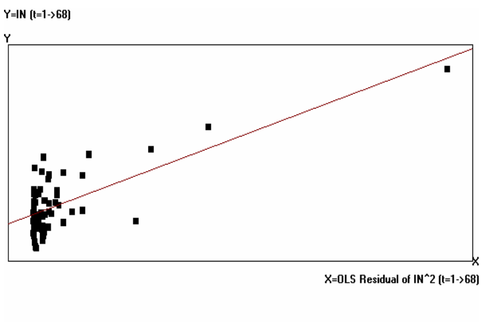

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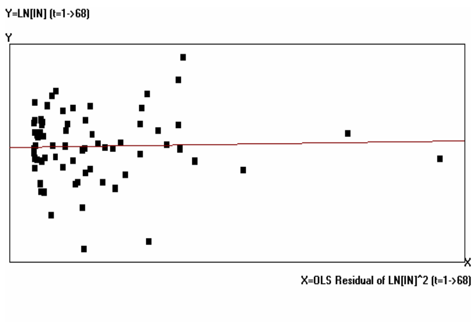

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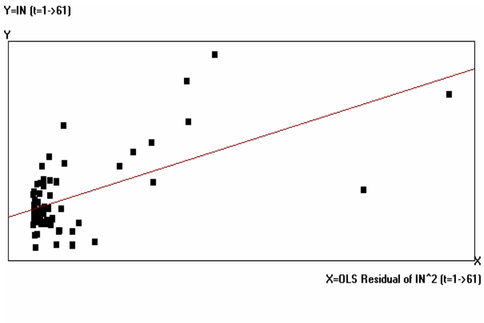

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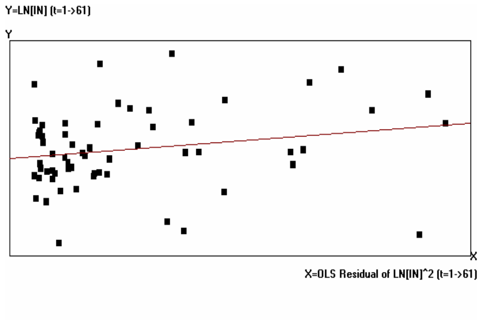

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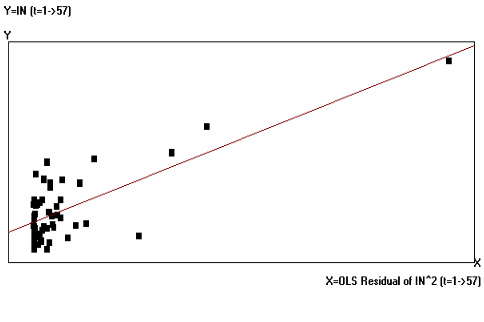

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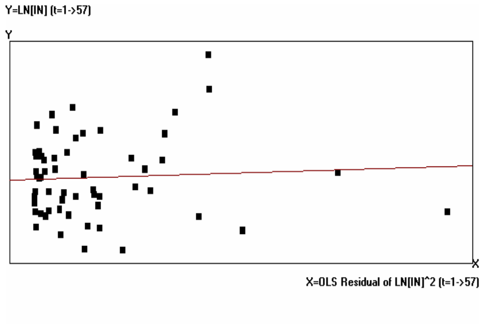

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