Innovations

Goal programming - input- output model for Iyiocha stream forest reserve, Delta state, Nigeria

Kesiena Tina Ogeh [1*] and Saka Oladunni Jimoh[2]
[*1]Department of Forestry and Wildlife, Delta State University, Abraka, Nigeria
[2]Department of Social and Environmental Forestry, University of Ibadan, Ibadan, Nigeria

[*1]Corresponding Author: **Kesiena Tina Ogeh**
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Abstract
Goal Programming (GP) and Input-Output (I-O.) model can contribute to suitable management of forests in Nigeria. Iyiocha Stream Forest Reserve (ISFR) has lost most of its indigenous timber species and Non-timber forest products (NTFPs) to unsustainable management. The sustainable level of outputs of the available forest resources (AFRs) in ISFR were determined using Goal Programming-Input-Output (GP-I-O.) model. Four villages were picked on the condition of closeness to ISFR: Illah, Ugbolu, Akwukwu and Aniwalo. Using random sampling 165 questionnaires were administered to the different forest stakeholders in ISFR. Information on timber and NTFPs; demand, production inputs (PIs) and AFRs were obtained. Projected demands (PDs) and PIs were estimated using standard procedures. One hundred and sixteen plots of 25m×25m in the plantations and 20 plots of 75m×75m in the natural forest using random sampling and systematic sampling respectively to collect data on available forest resources (AFRs). Timber, fuel-wood volumes and NTFPs quantities were estimated. The PDs, PIs and AFRs were used to estimate input-output coefficients (IOCs) and independent matrix (IM). The PDs, IM and AFRs were used to build the GP-I-O. model. The PDs are: Sawnwood (68,246.45m^3), taungya farm land (59.50ha), fuel-wood (13,433.70m^3), Morinda lucida bark (41,462kg), Tetrapleura tetraptera fruits (66,339.20kg), Treculia africana fruits (301,965kg), Napoleona vogelii stems (4616.10m^3), Olax subscorpioidea stems (3317m^3), Nauclea latifolia roots (27,697kg), Morinda morindoides stems (18,243.28kg) and access road (14.21km). The AFRs are: timber (1,495,035.81m^3), taungya farm (68.40ha), fuel-wood (24,766.74m^3), Morinda lucida bark (157,574.88kg), Tetrapleura tetraptera fruits (900kg), Treculia africana fruits (250kg), Napoleona vogelii stems (32,111.42m^3), Olax subscorpioidea stems (20.54m^3), Nauclea latifolia roots (12,256kg), Morinda morindoides stems (48,114.60kg) and access road (14.21km). The PIs are: land (875.42ha), fund (₦15,548,25), labour (3652man-days), land rent (₦10,000/ha) and access road (14.21km). The GP-I-O. model solution shows that taungya farm land (68.40ha) and access road (14.21km) are sustainably utilised while all the other AFRs are unsustainably utilised. The available forest resources are not adequate to deliver the projected demands. Improved inputs are required to boost production of the available forest resources.
***Keywords**: Forest, forest resources, forest management, multiple-use forest management, sustainability*

Introduction
Understanding the demand for forest resources by forest stakeholders and how forests and farmlands are used and controlled is a means of attaining suitable management of forests and sustainable agriculture, which do not focus only on short-term production but also on economic, social and environmental

sustainability (Mcintyre *et al*., 2009; Colfer and Pfund, 2011). The ecological, economic and social values stakeholders attach to and benefit from the forests should be considered in forest sustainability (Diaz-Balteiro and Romero, 2008; Aldea *et al.*, 2014). Sustaining ecological systems is an essential requirement in building productive economies, stable human communities, and in meeting values the public seek from forests. Human well-being is compromised if forest managers do not sustain essential functioning ecological systems.

The adoption of best method in sustaining forests and provision of varied forest goods and services, has been an issue of deliberation (Oriola, 2009). Goal programming (GP) and input-output (I-O.) analysis bridged this subject, by looking at protected areas and actively managed forestlands as complementary approaches if coordinated at landscape or regional scales (Poiani *et al*., 2000; Keles and Baskent, 2011). Applying Goal programming (GP) and input-output (I-O.) model in managing forest is needed to achieve broad sustainability of multiple objectives. Reaching a profitable level will at all times require an equilibrium involving diverse economic and ecological objectives, values and interests. With the increasing population of the forest communities; and changes in demand for forest resources, there is need for a management model that will involve the forest communities and their interests.

Study Area

The location of ISFR is in Delta State, Nigeria. It lies between latitudes 6°18′ and 6°24′North and longitudes 6°37′ and 6°40′East. The forest reserve was set up in the year 1969 and is 875.416ha (8.754km^2) in size. The plantations in ISFR are mainly of *Tectona grandis*) and Gmelina (*Gmelina* arborea).

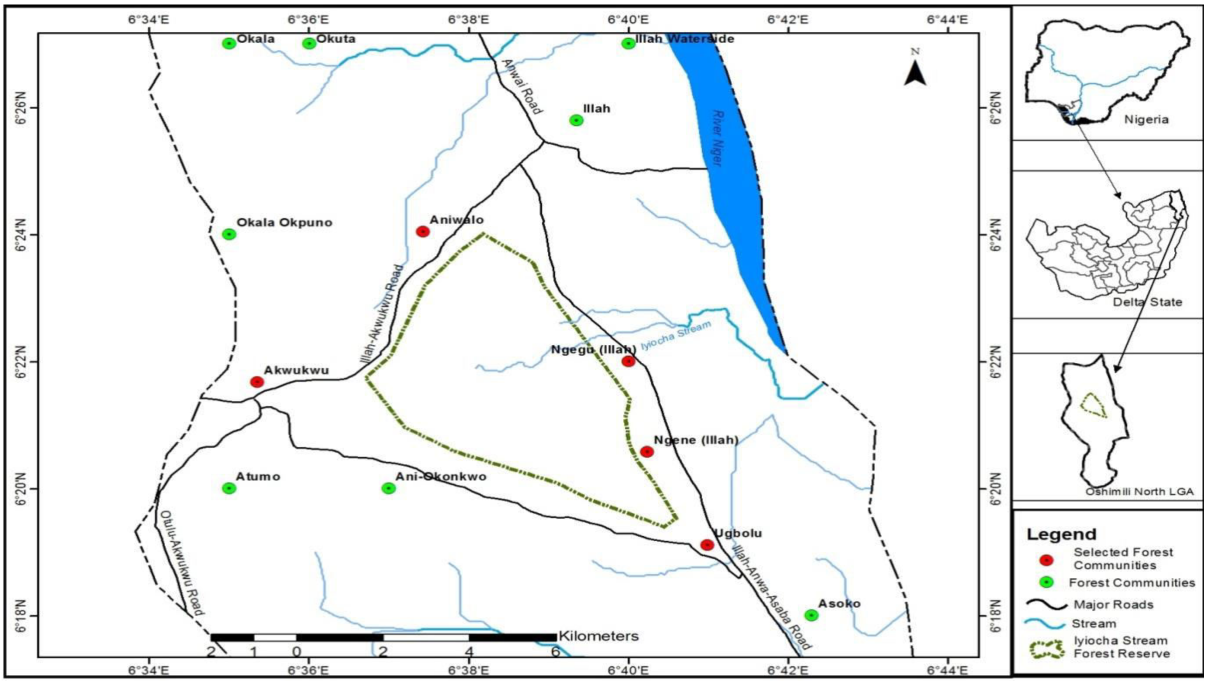

Figure 1.Map of ISFR and the Four Communities Selected.

Data Collection and Analysis

Four villages were picked on the condition of closeness to ISFR: *Illah*, *Ugbolu*, *Akwukwu* and *Aniwalo*. Random sampling was used to administer questionnaires to 165 forest stakeholders in ISFR. Information on forest resources harvested and demanded were obtained.

One hundred and sixteen temporary sampling plots (TSPs) were laid in the forest plantations comprising of nineteen age series: *Tectona grandis* 19-32 years, *Gmelina arborea* 31-32 years and 50 years, *Khaya ivorensis* 35 years and *Terminalia ivorensis* 35 years using stratified sampling technique. A line transects of 300m with a distance of 100m between transects were laid for one age series. Alongside each transects, plots of 25m×25m (625m^2) were sampled at 100m interval. Twenty plots were sampled in the natural forest using systematic sampling. Five line transects of 900m were laid with a distance of 450m between one transect and another. Plots of 75m×75m (5625m^2) with 4 sample plots were demarcated at interval of 225m beside each transect. Information were obtained on timber volume, fuel wood volume, NTFPs quantities and their sustainable levels.

Forest Resource Demand Estimate

The estimated demand for forest resources was obtained through structured questionnaire. A set of questionnaire was administered to the different forest resources harvesters. Information on timber harvested and quantity demanded, NTFPs harvested and consumed, the average amount harvested/consumed during wet and dry seasons were obtained.

Sawn wood demand was estimated following Aruofor, (2001) and FAO, (2010). The average *taungya* farm size per individual was estimated by dividing the total *taungya* farm size by the total number of *taungya* farmers. The additional *taungya* farm size demanded by *taungya* farmers was obtained from questionnaire survey responses. The quantity of fuel-wood harvested was estimated in cubic meter (Length× width× height). Thereafter, the average fuel wood consumed per individual was estimated; average fuel wood consumed by households over the average household size. The quantity of the bark of *Morinda lucida* consumed was calculated in kilogram, the volume of stems of *Napoleona vogelii* consumed was estimated, *Nauclea latifolia* root was weighed in kilogram and stems of *Morinda morindoides* consumed was estimated through weighing in kilogram. The fruits of *Tetrapleura tetraptera* were weighed in kilogram, *Treculia africana* (African breadfruit) was also weighed in kilogram and the volume and number of stems of *Olax subscorpioidea* consumed was estimated. The average consumption of each of the NTFPs was estimated. The average consumption per person for the NTFPs selected was estimated; average consumption for the particular NTFPs over the average household size.

In estimating the demand level for each of the forest resources under consideration, it was assumed that the forest reserve is managed to provide the demand of Oshimili North LGA. It has a population of 118,540 from 2006 National Population Census (NPC) and a projected population of 165,848 in 2017. Total consumption (TC) was obtained by multiplying the average consumption of each forest resource by the projected population.

TC= $Average\ consumption\ per\ individual\ \times projected\ population$ ....Equation (1)

Where

TC= total consumption

Available Resource Inputs

The production inputs for timber and the NTFPs were assessed with the information from respondents and Conservation Department. The unit of land available and required for the production of timber and NTFPs was estimated based on the information obtained from Conservation Department and inventory. Estimation of financial input was done by estimating the money spent on the maintenance and protection of ISFR for one year; cost of maintenance of equipments and vehicles and the cost of capital in terms of bank interest, if the money was borrowed from the bank. The percentage cost charged on timber and NTFPs in the natural forest was estimated. The percentage cost charged on timber from government and the percentage cost charged on NTFPs in the plantation was also estimated. For NTFPs other cost components include storage/preservation costs, cost of depreciation on equipments, cost of transportation, and cost of processing and packaging where applicable.

Field Inventory/Estimate of Available Forest Resources

Individual trees of 10cm diameter at breast height (DBH) and above, within each plot of 25m×25m in plantations and 50m×50m in natural forest were identified and measured. Non-timber forest products (NTFPs) that are of importance to the forest communities which were identified through questionnaire administered were assessed; counted and measured in each of the plots. The harvested parts were recorded. The AFRs in ISFR were determined with the information from the field inventory.

Output from *taungya* farm was in two forms; wood component and crop produce component. The volume estimate of wood component was obtained following Husch *et al*. (2003) while the crop produce was estimated in kilograms from field observation. The sustainable level of harvesting (output) of fuel-wood was estimated in cubic meter (Length× width× height) per plot both in the natural forest and plantations. Harvesting was observed from February, 2017 to February, 2019. The sustainable level of harvesting (output) of each NTFP was estimated by observing stands per plot both in the natural forest and plantations. Harvesting was observed from February, 2017 to February, 2019. Estimation of available quantities was done using the information obtained from the inventory of both natural forest and plantation, those who are familiar with ISFR and forest users. The number of stands per plot for each plant was estimated and thereafter stands per hectare was estimated during the inventory. The bark of *Morinda lucida* was calculated in kilogram, the volume and number of stems of *Napoleona vogelii* available was estimated, *Nauclea latifolia* root was weighed in kilogram and the mass in kilogram and number of stems of *Morinda morindoides* available in each plot was estimated. *Tetrapleura tetraptera* fruits were weighed in kilogram, *Treculia africana* (African breadfruit) was also weighed in kilogram and the volume and number of stems of *Olax subscorpioidea* available in each plot was estimated.

Volume of each tree was estimated using Newton's Formula Husch *et al*. (2003)

$$V=\frac{H\pi}{24}\left[Db^2+4Dm^2+Dt^2\right] \text{ .... Equation (2)}$$

Where

V = stand volume (m^3); H= Height (m); Db= Diameter at the base; Dm= Diameter at the middle; Dt= Diameter at the top and π = 3.142

The sustainable level of harvesting for timber (in natural forest, plantations and *taungya* farms) was calculated using periodic annual increment (P.A.I) formula.

$$P.A.I=\frac{V_1-V_2}{X_1-X_2} \text{ .... Equation (3)}$$

Where

V= Volume of different ages of trees ; X= Ages of tree

Data Analysis

The Goal Programming-Input-Output (GP-I-O.) Model

Description of Model Variables and Specification of Constraints

The major variables include: management activities (Z); goal level (Y) for each activity (PDs); the AFRs (R); the IOCs for the multiple-use management problem and the input-output technology matrix (A). The GP-I-O model used by Chang and Buongiorno (1981) and applied by Jimoh (2002) was adopted for this study.

Input-Output Technology Matrix (A)

The I-O. Technology Matrix was determined by estimating the proportion of a given resource or activity required to reproduce one unit of that activity as well as its contribution to the production of another activity or output in the same environment.

I-O$(a_{ij}) = \frac{x_{ij}}{x_j}$ .... Equation (4)

Where

a_{ij}= Marginal input coefficient; x_{ij} = The proportion of a given product i, required to reproduce the equivalent of that product j in the same environment at a given time; X_j = The output j per hectare of the product under reference

Model Formulation

Lexicographic or pre-emptive goal programming was used to minimise deviation from a particular goal by placing more priority on higher goals than priority with lower goals.

Mathematical Representation of the Model

The mathematical representation of the GP-I-O. model is given below:

Minimise Z $=\sum P_k D_k N_i^+ + P_k D_k N_i^-$ .... Equation (5)

Subject to: (i)$(1-A)X + DN_i^+ + DN_i^-$ .... Equation (6)

For i = 1, 2, 3, ..., m

(ii) $C_{ij}X_{ij} = R_i$ .... Equation (7)

For i = 1, 2, 3, ..., m

(iii) $X_i = Y_j$.. Equation (8)

For j = 1, 2, 3,....., m

(iv) $DN_i^+ \geq 0$ .... Equation (9)

(v) $DN_i^- \geq 0$.. Equation (10)

Where

X_{ij} = Input 'i' of a resource required to produce a unit of output 'j' for that resource; C_{ij} = Element of a fixed cost that do not change with the level of production/output; A_{ij} = Marginal input coefficient; R_i = The available resources; X_i= A measure of the i^{th} input; Y_j = Estimated demand for j^{th} output; P_k = K^{th} Ordinal priority factor; DN_i^- = Negative deviation of goal achievement from the set target; DN_i^+ = Positive deviation of goal achievement from the set target

Results

Estimate of the Projected Quantity of the Forest Resources Demanded

The estimated average of the forest resources demanded per person is shown in Table 1. Estimated demand per individual for the forest resources reflects the choice of the forest communities over the forest resources in order of importance. The projected quantity of forest resources demanded is shown in Table 2.

Table 1.Estimate of the Quantity of the Forest Resources Demanded

S/No	Forest Resources	Average Demand Per Person
1	Timber from plantation and natural forest	287.7400m^3
2	*Taungya* farm land	1.600hectares
3	Fuel-wood	0.0810m^3 during dry season and 0.0570m^3during rainy season
4	*Morinda lucida* bark	0.2500kg
5	*Tetrapleura tetraptera* fruit	0.4000kg
6	*Treculia africana* fruit	1.8750kg
7	*Napoleona vogelii* stem	0.0250m^3

8	*Olax subscorpioidea* stem	0.0200m^3
9	*Nauclea latifolia* root	0.1670kg
10	*Morinda morindoides* stem	0.1100kg

Table 2 Estimate of the Projected Quantity of the Forest Resources Demanded

S/No	**Forest Resources**	**Projected Quantity Demanded/Management Goal (Y)**
1	Sawn-wood from plantation and natural forest	68,246.4500m^3
2	*Taungya* farm land	59.5000hectares
3	Fuel-wood	13,433.7000m^3
4	*Morinda lucida* bark	41,462kg
5	*Tetrapleura tetraptera* fruit	66,339.2000kg
6	*Treculia africana* fruit	301,965kg
7	*Napoleona vogelii* stem	4616.1000m^3
8	*Olax subscorpioidea* stem	3317m^3
9	*Nauclea latifolia* root	27,697kg
10	*Morinda morindoides* stem	18,243.2800kg
11	Maintained access road	14.2110km

Estimate of the Sustainable Harvest Level for Each of the Forest Resources

The number of indigenous and exotic tree species, stands of NTFPs and size of *taungya* farms in hectare are shown in Table 3. The number of indigenous and exotic tree species and stands of NTFPs in the plantation exceeds that of the natural forest. The total available forest resources and the forest resources that are harvested from the forest reserve in a year are shown in Table 4.

Table 3.Estimate of Available Forest Resources in Hectare

S/No	**Forest Resources**	**Natural Forest (hectare)**	**Plantation (hectare)**	***Taungya* Farm (hectare)**
1	Timber in plantation and natural forest	52 trees (> 10cm DBH)	250 trees (> 10cm DBH)	13 trees
2	*Taungya* farm land			35.6 hectares
3	Fuel-wood	1.1044m^3	5.8824m^3	
4	*Morinda lucida*			5 stands
5	*Tetrapleura tetraptera* fruit	2 stands		1 stand
6	*Treculia africana*	1 stand		
7	*Napoleona vogelii* stem	16 stands	96 stands	
8	*Olax subscorpioidea* stem		112 stands	
9	*Nauclea latifolia* root		56 stands	
10	*Morinda morindoides* stem	12 stands	40 stands	

Table 4.Estimate of the sustainable level of Forest Resources

S/No	**Forest Resources**	**Amount of available resources**	**Harvesting Level per Year**
1	Timber volume in plantation and natural forest	1,495,035.8100m^3	694.4200m^3
2	*Taungya* farm land	68.4000hectares	-

3	Fuel-wood	24,766.7400m³	8,060m³
4	*Morinda lucida* bark	157,574.8800kg	143kg
5	*Tetrapleura tetraptera* fruit	900kg	300kg
6	*Treculia africana* fruit	250kg	250kg
7	*Napoleona vogelii* stem	32,111.4200m³	190kg
8	*Olax subscorpioidea* stem	20.5400m³	9.5000m³
9	*Nauclea latifolia* root	12,256kg	143kg
10	*Morinda morindoides* stem	48,114.6000kg	190kg
11	Maintained access road	14.2110km	-

Estimate of Available Resource Inputs-Outputs

Table 5 shows the available inputs and the amount available in the management of the forest resources. An average budget of ₦15,548,250 is allocated for the management of the forest reserve (the fund allocated do not follow a definite pattern, because of this, an average budget per annum was estimated). A total of 3652 man-days of labour per annum was estimated for all the management activities. Land rent for *taungya* farming is ₦10,000 per hectare (2.5acre) per annum. The value of timber is ₦25,000 per 50 stumps and that of fuel wood is ₦10,000 quarterly per fuel wood harvester. An average cost of ₦52,776 was estimated for road maintenance.

Table 5.Available Inputs-Outputs

S/No	Inputs	Amount
1	Land area	875.4160hectares
2	Average budget	₦15,548,250
3	Labour	3652man-days
4	Land rent	₦10,000 per hectare (₦4000 per acre)
5	Permit (Value of timber)	₦25,000
6	Permit (Value of fuel wood)	₦10,000
7	Access road	14.2110km
8	Average cost of road maintenance	₦52,776

Source: Conservation Department, Delta State Ministry of Environment, 2018

Input-Output (I-O.) Coefficients for the Management Activities

The I-O. coefficient of each of the management activities is shown in Table 6. While the I-O. matrix is shown in Table 7. From the result, a small amount of inputs are required to produce an output of 0.2000m³ of timber in both plantation and natural forest in one hectare of land. The inputs of *Taungya* farming which are more compared to timber management activity yield an output of 2,313kg of *taungya* farm produce in one hectare of land. This could be attributed to the quantity of fund, labour and road availability. In case of fuel-wood, a small amount of the inputs required for its production gave a small output (0.0028m³) of fuel-wood. A small amount of the inputs required for production of *M. lucida* also produced a small amount of output (0.0941kg) in one hectare of land.

For *T. tetraptera*, large amount of inputs was estimated, which produced a small amount (0.0005kg) of *T. tetraptera* fruits in one hectare of land. More inputs were also estimated for *Treculia africana* which produced 0.0001kg of *Treculia africana* fruit in one hectare of land. The estimated inputs for *N. Vogelii* were small and the output (0.0037m³) estimated was also small. The inputs estimated for the production of *O. Subscorpoidea* stem are large and a small amount of output (0.0001m³) of *O. Subscorpoidea* stem was produced in one hectare of land. This could be attributed to the small amount of *O. Subscorpoidea* stem available in the forest reserve.

The inputs required for the production of *N. Latifolia* are small in amount and they also produced a small amount of output (0.1226kg) of *N. Latifolia* in one hectare of land. The estimated inputs for the production of *M. morindoides* yield a small amount of output (0.0055kg) in one hectare of land. A large amount of inputs is required for access road maintenance. It is expected that more inputs will be required in the maintenance of access road within the forest reserve for various activities and its sustainable management (SM).

Table 6.Input-Output (I-O.) Coefficients (Forest Reserve Resources, Inputs Required, Estimated demand and Available Resources)

S/No	Activity and Forest Resources Output/ha/yr	AMOUNT OF INPUTS - OUTPUT REQUIRED Land (ha)	Fund (₦)	Labour (days)	Access road (km)	
1	Timber production in plantations and natural forest	1.0000	11.2069	0.0024	0.0001	0.2000m^3
2	*Taungya* farming	1.0000	244951.8947	53	2.2854	2313kg
3	Fuel-wood production	1.0000	676.5006	0.1475	0.0063	0.0028m^3
4	*M. lucida* bark production	1.0000	106.3286	0.0232	0.0010	0.0941kg
5	*T. tetraptera* fruit production	1.0000	18616	4.0578	0.1737	0.0005kg
6	*Treculia africana* fruit production	1.0000	67019	14.608	0.6253	0.0001kg
7	*N. vogelii* stem production	1.0000	521.7681	0.1137	0.0049	0.0037m^3
8	*O. subscorpioidea* stem production	1.0000	815,711.76	178	7.6106	0.0001m^3
9	*N. latifolia* root production	1.0000	1367.0624	0.2980	0.0128	0.1226kg
10	*M. morindoides* stem production	1.0000	348.2252	0.0759	0.0032	0.0055kg
11	Access road maintenance	1.0000	1178995.4930	257	1.0000	1.0000km

Table 7 Input-Output (I-O.) Independent Matrix for the Management Activities (Forest Reserve Resources)

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	10.4549	228515.6671	631.1073	99.1939	17367.19	62521.8865	486.7574	760977.1972	1275.3322	324.8592	1099885.4150
X_2	1.6943	37032.6057	102.2755	16.0751	2814.4780	10132.1200	78.8825	12332.8223	206.6767	52.6458	178244.3340
X_3	0.4959	10839.9068	29.9373	4.7054	823.8329	2965.7990	23.0899	36097.8397	60.4969	15.4101	52174.3457
X_4	0.0005	10.7255	0.0296	0.0047	0.8107	2.9345	0.0228	35.7170	0.0599	0.0152	51.6239
X_5	0.0005	10.6671	0.0295	0.0046	0.8107	2.9185	0.0227	35.5222	0.0595	0.0152	51.3424

X_6	0.0005	10.6671	0.0295	0.0046	1.6018	2.9185	0.0227	35.5222	0.0595	0.0152	51.3424
X_7	0.0010	21.0764	0.0582	0.0091	0.6513	5.7665	0.0449	70.1863	0.1177	0.0299	101.4444
X_8	0.0004	8.5703	0.0237	0.0037	0.6402	2.3448	0.0183	28.5399	0.0478	0.0122	41.2505
X_9	0.0004	8.4241	0.0233	0.0037	1.6018	2.3048	0.0179	28.0531	0.0470	0.0120	40.5468
X_{10}	0.0010	21.0764	0.0582	0.0091	58.6716	5.7665	0.0449	70.1863	0.1176	0.0299	101.4444
X_{11}	0.0353	771.9945	2.1321	0.3351	66339.2	211.2177	1.6444	2570.8093	4.3085	3715.7429	3715.7429

Note: X_1, X_2, X_3 .... X_{11} are the management activities (forest reserve resources)

Goal Programming-Input-Output (GP-I-O.) Model Analysis

The various goals, goal levels (projected demands) and their achieved levels are shown in Table 8. The estimated demand, the priorities assigned to the estimated demand, inputs available and forest resources available were used to build the GP-IO model. Various goal fittings were used in the analysis to ascertain the best solution for the goal level achieved. The unused forest resources were estimated from the forest resources available and result of run 1 as shown in table 9.

Table 8: Optimum Level of Goal Level Achieved Based on Goal Priority Ranking and Goal Fitting

Goal	**Goal Level**	**Goal Priority Ranking**	**Run 1 Goal Level Achieved**	**Goal Priority Ranking**	**Run 2 Goal Level Achieved**	**Goal Priority Ranking**	**Run 3 Goal Level Achieved**
Sawn-wood from plantation and natural forest	68,246.4500m³	1	4206.5537	2	4206.5537	1	8413.1071
Taungya farm	59.5000hectares	2	68.4000	1	68.4000	2	136.8000
Fuel-wood	13,433.7000m³	3	199.5428	3	199.5428	3	399.0855
Morinda lucida bark	41,462kg	4	0.1974	4	0.1974	4	0.3949
Tetrapleura tetraptera fruit	66,339.2000kg	5	0.1964	5	0.1964	5	0.3927
Treculia africana fruit	301,965kg	6	0.1963	6	0.1963	6	0.3927
Napoleona vogelii stem	4616.1000m³	7	0.3880	7	0.3880	7	0.7760
Olax subscorpioidea stem	3317m³	8	0.1578	8	0.1578	8	0.3155

Nauclea latifolia root	27,697kg	9	0.1151	9	0.1151	9	0.3104
Morinda morindoides stem	18,243.2800kg	10	0.3880	10	0.3880	10	0.7760
Maintained access road	14.2110km	11	14.2110	11	14.2110	11	28.4220

Table 8. (contd.)

Goal Priority Ranking	Run 4 Goal Level Achieved	Goal Priority Ranking	Run 5 Goal Level Achieved	Goal Priority Ranking	Run 6 Goal Level Achieved	Goal Priority Ranking	Run 7 Goal Level Achieved	Goal Priority Ranking	Run 8 Goal Level Achieved
1	8413.1071	1	1261.9960	1	4206.5537	1	4206.5537	1	4206.5537
2	136.8000	2	20.5200	2	68.4000	2	68.4000	2	68.4000
3	399.0855	3	59.8628	3	199.5428	3	199.5428	3	199.5428
4	0.3949	4	0.5923	4	0.1974	4	0.1974	4	0.1974
5	0.3927	5	0.5891	5	0.1964	5	0.1964	5	0.1964
6	0.3927	6	0.5891	6	0.1963	6	0.1963	6	0.1963
7	0.7760	7	1.1639	7	0.3880	7	0.3880	7	0.3880
8	0.3155	8	0.4733	8	0.1578	8	0.1578	8	0.1578
9	0.3104	9	0.4652	9	0.1151	9	0.1151	9	0.1151
10	0.7760	10	1.1634	10	0.3880	10	0.3880	10	0.3880
11	28.4220	11	14.2633	11	14.2110	11	14.2110	11	14.2110

Table 9.Forest Resources Utilisation Analysis for Run 1

S/No	Forest Resources	Forest Resources Available	Forest Resources under-achieved	Forest Resources over-achieved	Unused Forest Resources
1	Timber volume in plantation and Natural Forest	1,495,035.8100m^3	4206.5537		1,490,829.2600
2	*Taungya* farm	68.4000hectares		68.4000	0
3	Fuel-wood	24,766.7400m^3	199.5428		24,567.2000
4	*Morinda lucida* bark	157,574.8800kg	0.1974		157,574.6800
5	*Tetrapleura tetraptera* fruit	900kg	0.1964		899.8000
6	*Treculia africana* fruit	250kg	0.1963		249.8000
7	*Napoleona vogelii* stem	32,111.4200m^3	0.3880		32,111.0300
8	*Olax*	20.5400m^3	0.1578		20.3800

	subscorpioidea stem				
9	*Nauclea latifolia* root	12,256kg	0.1151		12,255.8500
10	*Morinda morindoides* stem	48,114.6000kg	0.3880		48,114.2100
11	Maintained access road	14.2110km		14.2110km	0

Discussion

Estimate of the Projected Quantity of the Forest Resources Demanded

The result in Table 1 indicates a high average demand for timber (287.7400m^3) and *taungya* farm land (1.6000 hectare) annually in the study area which is reflected in their ranking. The average demand (0.0810m^3) for fuel-wood per person is more during dry season compared to the demand (0.0570m^3) on an annual basis during wet season. The reduction in fuel-wood demand during rainy season might be due to difficulty encountered by the harvesters in accessing the forest reserve for harvesting of fuel-wood during this season. The average demand for *Morinda lucida* (0.2500kg), *Tetrapleura tetraptera* (0.4000kg), *Treculia africana* (1.8750kg), *Napoleona vogelii* (0.0250m^3), *Olax subscorpioidea* stem (0.0200m^3), *Nauclea latifolia* (0.1670kg) and *Morinda morindoides* (0.1100kg) is low compared to timber, *taungya* farm land and fuel-wood demand.

A high projected demand of (68,246.4500m^3) was estimated for timber. This agrees with the statement of Iheke and Eziuche (2016), that timber components are widely harvested and are known as vast contributor to both national and local economies. A land size of 59.5000 hectares was estimated for *taungya* farming. This estimated figure signifies a high demand for more land for *taungya* farming and this agree with Ojo (2014), that more land are demanded for *taungya* farming and are made available to landless farmers. Through *taungya* farming there is an increased food crop production, income to farmers, production of exotic and indigenous forest species. *Taungya* farming has helped in conserving the biodiversity of ISFR. The high demand (13,433.7000m^3) for fuel wood in the study might result to degradation of ISFR. The projected demand is also high for *Morinda lucida* (41,462kg), *Tetrapleura tetraptera* (66,339.2000kg), *Treculia africana* (301,965kg), *Napoleona vogelii* (4616.1000m^3), *Olax subscorpioidea* stem (3317m^3), *Nauclea latifolia* (27,697kg) and *Morinda morindoides* (18,243.2800kg) which indicates the need for sustainable management the forest reserve.

The forest communities have varying demands that need to be satisfied which supports the observations of Cocks and Wiersum (2003); Lawes *et al*. (2004), that millions of people all over the world demand and make use of forest products in varying ways. For the demand to be met; there is a need to sustainably manage the forest reserve with regard to the estimated projected demand of forest resources. This aligns with the statement of Olujobi (2015), that the forest resources demanded by forest users has grown and need to be taken into consideration in forest management practices.

Estimate of the Sustainable Harvest Level for Each of the Forest Resources

The number of indigenous and exotic tree species and stands of NTFPs in the plantation exceeds that of the natural forest. This implies that if the undergrowths in the plantation are well managed through fire prevention and protection of regeneration they could contribute to biodiversity conservation and increase the range of benefits accruable from the forest. Majority of the available forest resources exceed the projected demand except in the case of *Tetrapleura tetraptera* fruit, *Treculia africana*, *Olax subscorpioidea* stem and *Nauclea latifolia* root which are low compared to the projected demand. The low available forest resources are mostly NTFPs which are used as food and medicine. It is expected that forest resources which are needed on daily basis by forest communities will have more demand and will outweigh the availability of those forest resources than other forest resources that are not needed on daily basis. Though, there are cases where the availability of the forest resources that are need on daily basis outweighs those forest resources demanded like in the case of available fuel-wood over projected demand.

Harvesting level of the available forest resources in the study was necessary to give insight on goal level obtainable in the GP-I-O. model in order to come up with a SM plan for the forest reserve. The estimated level of harvesting of the available forest resources provides information on what level of forest resources can be harvested from the forest reserve which aligns with the observation of Olujobi (2015), that in order to ensure the SM of forest reserves, inventory of the various forest resources available and harvested from forest reserves, the quantity harvested and evaluation of the harvested parts for each forest resource as well as the various uses of these forest resources are required. This will provide useful guide for the forest manager to take informed decisions about sustainable harvesting regimes as well as regeneration plans.

Estimate of Available Resource Inputs-Outputs

The inputs in Table 5 were estimated to give the insight of the various inputs available and which are necessary for the production of the management. This is to establish the relationship among the inputs and various activities taking place in the forest reserve which is similar to Soutsas (2005), which listed budget, land and personnel as the primary inputs required in resources planning in forests. He used GP-I-O. model in providing a linkage among management activities and the inputs. This study went further to identify land rent and access road as other inputs necessary in the SM of ISFR.

Input-Output (I-O.) Coefficients for the Management Activities

The I-O. coefficients are the inputs required for the production of timber in plantation and natural forest; *taungya* farm produce and access road maintenance yield a considerable amount of outputs. It implies that the production of these resources is profitable with the available inputs used in production which agrees with Jimoh (2002), that estimated a fund of ₦19.57, 139 man days of labour, ₦1,187.50 of land rent, access road of 0.001km to produced an available output of 2.1m^3 of sawn-wood in one hectare of land in natural forest in his work. In his work, the inputs for production of sawn-wood in natural forest yield more output compare to this work. The difference in outputs might be attributed to difference in locations and the land area of the forest where his study was done.

Fuel wood, *M lucida, T tetraptera, Treculia Africana, N vogelii, O subscorpoidea, N latifolia and M morindoides*; the inputs used for production of these resources are more than the output of these resources. It indicates that the present production of these resources is not sustainable with the inputs used in production. Chang and Buongiorno (1981), estimated that one acre of merchantable stand, 0.0012 mile of road maintenance, 0.0044 mile of road construction, 0.0093 man-day of labour and 5.7316 budget dollars as the inputs required to produce 1 acre of timber harvest. Though the timber harvest and the inputs required to manage the activity in their work differ from the ones in this study; from their work, the inputs required in timber harvest management activity are low compared to the output of the management activities. The difference in results might also be ascribed to the difference in location, the land area of the forest and the time lab in their study and this study.

Goal Programming-Input-Output (GP-I-O.) Model Analysis

Run 1: Goals level, goal priority ranking, inputs available and forest resources level were unchanged. A goal level of 4206.5537m^3 of sawn-wood from plantation and natural forest was achieved. The goal level achieved for sawn-wood from plantation and natural forest is above the periodic annual increment. This implies that the harvesting level of 694.4200m^3 can be sustained. *Taungya* farming was over-achieved by 8.9 hectares. The over achievement of *taungya* farming is an indication that the forest is capable providing the needed *taungya* farm land in the study area. This means there is an excess land in the forest for *taungya* farming which could be directed towards achieving other resources that are of importance to the forest communities. Fuel wood was under-achieved by 13,234.1597m^3. The harvesting level

8,060m^{3}of fuel wood is high compared to the goal level achieved for fuel wood. This indicates that it is required to reduce fuel wood harvesting level for it to be available in a sustainable manner.

From Table 8, *Morinda lucida* bark, *Tetrapleura tetraptera*, *Treculia africana* (African breadfruit), *Napoleona vogelii* stem, *Olax subscorpioidea* (broom plant), *Nauclea latifolia* root and *Morinda morindoides* stem were all under-achieved. The under achievement of these forest resources signifies that the projected demand cannot be achieved for those forest resources. Therefore, the inputs for those forest resources should be increased in order to increase production. The 14.2110km of maintained access road was achieved. This implies that the maintenance of access road can meet the production and access of the forest resources. An optimum level of 18.3291 was achieved for all the goals. The optimum level indicates the minimum total goal for deviating from all the goals. This result is different from the results of Chang and Buongiorno (1981); Jimoh (2002) and Shaik *et al*. (2010). In the studies the attainment of the various goal levels of forest resources could be redistributed to achieve the set goals. All the studies are geared towards SM of the various forest reserves.

Run 2: Change in goals priority ranking while goals level, inputs available and forest resources level were constant. *Taungya* farming was assigned first priority. The same result obtained in run 1 was obtained in run 2 in the analysis. This implies that change in priority level has no effect on the goal level achievement.

Run 3: Forest resources level was doubled while goals level, goals priority ranking and inputs available were unchanged. A goal level of 8413.1071m^3 of sawn-wood from plantation and natural forest was achieved against the estimated demand of 68,246.45m^3. *Taungya* farming was over achieved by 136.8000hectares. A goal level of 28.4220km was over achieved for access road maintenance. While all other goals level were under achieved.

When forest resources level were doubled in run 6 while goals level, goals priority ranking and inputs available were unchanged; *taungya* farming and access road maintenance were over achieved. The over achievement of access road maintenance can improve SM of the forest reserve. The over achievement of land for *taungya* farming in this run is very high and can lead to land hunger in the study area. This could result in competition in using the forest reserve land for other uses, which could pose threat to the sustainable management of the forest reserve. The goal level achieved for timber in plantation and natural forest and all other goal levels were under-achieved when the forest resources level was doubled. This implies that an increase in the available resources of the forest reserve while inputs available for management and projected demand for forest resources are constant does have a significant effect on goals level achieved. This also implies that when the forest resources level doubled, the optimum level for all the goals level increases. This does not align with Misir and Misir (2007), were all the goals (wood production, water production and soil production) were all achieved. They also reported that an increase in water production led to an increase in wood production.

Run 4: Goals level reduced by 50%, forest resources level doubled and goals priority ranking and inputs available were unchanged. Run 6 result was obtained in run 7. This indicates that a reduction in goals level by 50%, increase in resources and keeping goals priority ranking and inputs constant has no effect on the GP-I-O. result.

Run 5: Forest resources level was tripled, goals level reduced by 30% while goal priority ranking and inputs available were unchanged. There was a sharp reduction goals level achieved for all the resources. Sawn-wood from plantation and natural forest, *Taungya* farming, Fuel wood, *Morinda lucida* bark, *Tetrapleura tetraptera*, *Treculia africana* (African breadfruit), *Napoleona vogelii* stem, *Nauclea latifolia* root and *Morinda morindoides* stem were all under-achieved. Maintenance of access road was achieved by 14.2633km. This implies that an increase in forest resources level and a reduction in goals level did affect the goal level achievement.

Run 6: Inputs level increased by 25% while goals priority ranking, goals level, inputs available and forest resources level were constant. The result obtained in run 1 was also obtained in run 12. An increase in inputs level by 25% has no effect on the goal level achieved. A goal level of 4206.5537m^3 of sawn-wood from plantation and natural forest was achieved against the projected demand of 68,246.4500m^3. *Taungya* farming was over-achieved by 8.9hectares against 59.5000hectares of the quantity demanded. Fuel wood was under-achieved by 13,234.15972m^3. *Morinda lucida* bark, *Tetrapleura tetraptera*, *Treculia africana* (African breadfruit), *Napoleona vogelii* stem, *Olax subscorpioidea* (broom plant), *Nauclea latifolia* root and *Morinda morindoides* stem were all under-achieved. Maintenance of access road was achieved by 14.2110km.

Run 7: Inputs level increased by 50% while goals priority ranking, goals level, inputs available and forest resources level were constant. The result obtained in run 1 was also obtained in run 12. An increase in inputs level by 50% has no effect on the goal level achieved.

Run 8: Inputs level increased by 75% while goals priority ranking, goals level, inputs available and forest resources level were constant. The result obtained in run 1 was also obtained in run 14. An increase in inputs level by 75% has no effect on the goal level achieved.

In Runs 6-8 inputs level were increased by 25%, 50% and 75% while goals priority ranking, goals level, inputs available and forest resources level were constant. There was a difference in the optimum level for the three runs. When land, fund, labour, land rent and value of forest resources were raised no clear variation in the goals level achievement. This implies that an increase in inputs has no effect on attainment level of the goals but did affect the outputs of the available forest resources. An increase in inputs will lead to more outputs of the available forest resources.

Conclusion

The study has revealed the quantity of the forest resources demanded, the inputs available for production, the outputs and the optimum level of the forest resources with GP-I-O. The projected demand for four forest resources (timber, *taungya* farm land, fuel wood and *Napoleona vogelii* stem) is below the forest resources outputs while the projected demand for six of the forest resources (*Morinda lucida* bark *Tetrapleura tetraptera* fruit, *Treculia africana* fruit, *Olax subscorpioidea* stem, *Nauclea latifolia* root and *Morinda morindoides*) exceeded the forest resources outputs. Almost all the forest resources outputs are below the projected demand for the forest resources. The harvest level of timber, *Morinda lucida* bark *Napoleona vogelii* stem, *Nauclea latifolia* root and *Morinda morindoides* stem could be sustained for a long period of time. Fuel wood may possibly be sustained for a period of three years; while *Tetrapleura tetraptera* fruit, *Treculia africana* fruit and *Olax subscorpioidea* stem which outputs are very low can't be sustained. The available inputs are land, fund, labour and access road which are required for the production of the management goals.

The inputs required to produce a unit of a forest resource from a unit of another forest resource need to be increased for production of the forest resources to increase. The GP-I-O. model is also very important in multiple-use forest management (MFM) plan. The optimum levels of the forest resources were achieved with the model. This provides information on how to achieve the projected demand with the forest resources outputs. From the result of the model, nine of the management activities (timber, fuel wood, *Morinda lucida* bark *Tetrapleura tetraptera* fruit, *Treculia africana* fruit, *Olax subscorpioidea* stem, *Nauclea latifolia* root and *Morinda morindoides*) were under achieved while two (*taungya* farm land and access road) were achieved. For the projected demand of the forest resources to be met in ISFR, sustainable production of the forest resources through increased inputs and outputs such as land, fund, labour, land rent, permit and access road thereby enhancing sustainable development of the forest area.

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Corresponding E-mail: **ogehkest@gmail.com**