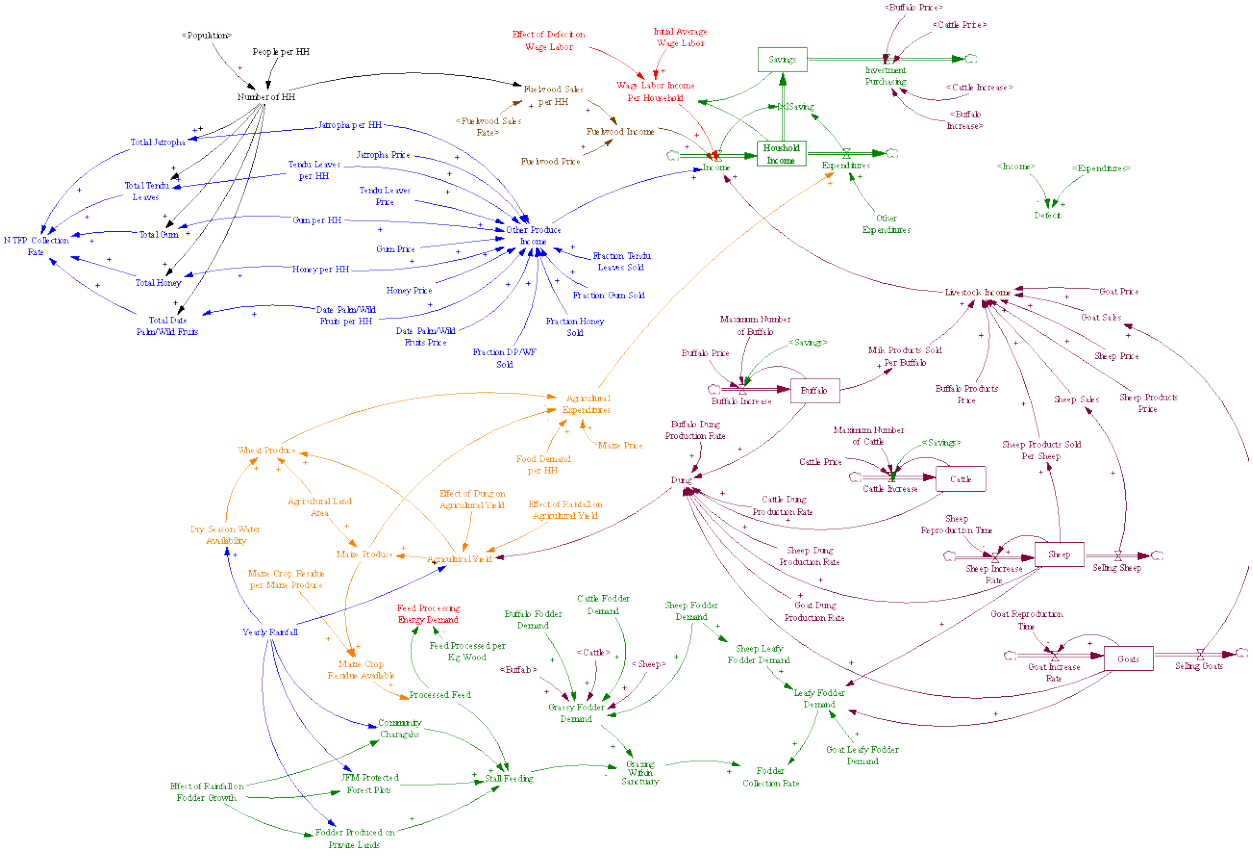
Appendix: Equation List

Livelihoods

Due to unreliable resource availability, KWLS households are forced to alter their behaviors in order to meet their economic and sustenance needs. Livelihood needs are met through many different resources, many of which come from the Kumbhalgarh sanctuary. In seasons of poor resource supply, these households may increase resource collection rates, diversify collected products, or sell previously obtained goods such as livestock.

Figure 28: Livelihood Sources



(030) Defecit=IF THEN ELSE((Income-Expenditures)<0, Expenditures-Income, 0)
Units: Rupees/Month

(048) Expenditures=Agricultural Expenditures+Other Expenditures
Units: Rupees/Month

(086) Income=Fuelwood Income+Livestock Income+Other Produce Income+Wage Labor Income Per Household
Units: Rupees/Month

(085) Houshold Cash= INTEG (Income-Saving-Expenditures,1000)
Units: Rupees

(133) Saving=IF THEN ELSE(Income>Expenditures, Income-Expenditures, 0)
Units: Rupees/Month

(134) Savings= INTEG (Saving-Investment Purchasing,0)
Units: Rupees

(097) Investment Purchasing=Cattle Increase* Cattle Price+Buffalo Increase*Buffalo Price
Units: Rupees/Month

(126) Other Expenditures=2500
Units: Rupees/Month

Fuelwood Collection

There is an increase in need for fuelwood by the resident communities as well as the communities further from the conserved areas. The population of sanctuary villages continues to increase, driving up the demand of timber, used as fuelwood for cooking and heating. Most of the timber resources outside the sanctuary have been depleted; currently nearly all of the fuelwood extraction is from sanctuary forest. Nearby communities not located in or along the periphery of the sanctuary continue to demand timber from sanctuary communities. Monetization of resources has led the local communities living in the vicinity of the protected forests to cut, transport, and sell fuelwood in the outlying villages, where communities are affluent and willing to pay for the resources. Brick kilns, hotels, and other businesses also meet their energy needs by purchasing sanctuary resources. The advent of road networks and transport facilities has accelerated the sales of forest product, making it easier to transport large quantities of materials further distances in less time. Approximate calculations reflect that 10% of the total fuelwood currently collected is sold in the local market, thus, both sanctuary villages and more distant villages are becoming increasingly dependent on resources from conserved and protected areas.

(008) Average Sales Time=1
Units: Month

(036) Effect of Defecit on Fuelwood Collection([(0,0)-(4.83e+007,400000)],(0,161000),(483000,241500),(4.83e+006,241500),(4.83e+007,241500))
Units: Kg of Wood/Month

(016) "Bundles collected/Woman/Month"=20
Units: bundle/(Month*person)

(025) Consumption Time=20/15
Units: Month

(022) Collection Rate=IF THEN ELSE(Defecit>0, Effect of Defecit on Fuelwood Collection(Defecit/Initial Defecit), (Population*"Male/Female Ratio"*"Kg/Bundle"*"Bundles collected/Woman/Month"))
Units: Kg of Wood/Month

(026) Cooking Energy Demand=Cooking Energy Demand Per Capita*Population
Units: Kg of Wood/Month

(027) Cooking Energy Demand Per Capita=120
Units: Kg of Wood/person/Month

(027) Stove Efficiency=1
Units: Kg of Wood/Kg of Wood

(062) Fuelwood Collection Rate=Collection Rate+Total CH Energy Demand-Fuelwood in Village/Consumption Time
Units: Kg of Wood/Month

(063) Fuelwood Consumption Rate=Total CH Energy Demand
Units: Kg of Wood/Month

(064) Fuelwood in Village= INTEG (Fuelwood Collection Rate-Fuelwood Consumption Rate-Fuelwood Sales Rate,30000)
Units: Kg of Wood

(065) Fuelwood Income=Fuelwood Price*Fuelwood Sales per HH
Units: Rupees/Month

(066) Fuelwood Price=2
Units: Rupees/Kg of Wood

(067) Fuelwood Sales per HH=Fuelwood Sales Rate/Number of HH
Units: Kg of Wood/Month

(068) Fuelwood Sales Rate=MIN(Outside Fuelwood Demand, IF THEN ELSE(((Fuelwood in Village/Average Sales Time)-Fuelwood Consumption Rate)<0, 0, (Fuelwood in Village/Average Sales Time)-Fuelwood Consumption Rate))
Units: Kg of Wood/Month

(081) Heating Energy Demand=Heating Energy Demand Per Capita*Population
Units: Kg of Wood/Month

(082) Heating Energy Demand Per Capita=30
Units: Kg of Wood/person/Month

(089) Initial Defecit=1
Units: Rupees/Month

(128) Outside Fuelwood Demand=250000
Units: Kg of Wood/Month

(107) "Male/Female Ratio"=0.5
Units: person/person

(101) "Kg/Bundle"=20
Units: Kg of Wood/bundle

(155) Total CH Energy Demand=Heating Energy Demand+Cooking Energy Demand
Units: Kg of Wood/Month

Wage Labor Income

Many of the people living in villages in and around the sanctuary participate in wage labor to supplement the household income. Wage labor consists of both seasonal labor and permanent migration. Permanent migration occurs when a family member relocates to another region to work and send this earned money back to the family. Seasonal migration involves sporadic wage labor participation for short periods of time when additional income is necessary and work is available. This commonly involves payment for farming work in other villages, both distant and nearby.

(037) Effect of Defecit on Wage Labor([(-300,0)-(0,20000)],(-300,11200),(-200,11200),(-200,8800),(-100,8800),(-100,6400),(-0.001,6400),(0,4000))
Units: Rupees/Month

(088) Initial Average Wage Labor=4000
Units: Rupees/Month

(090) Initial Defecit Amount=1
Units: Rupees

(161) Wage Labor Income Per Household=IF THEN ELSE((Houshold Income+Savings)<0, Effect of Defecit on Wage Labor((Houshold Income+Savings)/Initial Defecit Amount), Initial Average Wage Labor)
Units: Rupees/Month
Total wage labor earnings per household

Other Produce Income

Collection of NTFP from the sanctuary contributes to the livelihood of the people. When present in the forest, small amounts of date palm and other fruits are collected strictly for household consumption. Honey is seasonally collected and exclusively sold at markets in nearby villages. This resource provides direct monetary income; none of the honey collected is consumed by the households. In past years, gum has been collected for household use, but is no longer available. Forest degradation has caused this resource to become scarce and even nonexistent in most areas. Likewise, tendu leaves, also commonly known as bidi leaves, were at one time collected and sold in neighboring villages. Large amounts of these leaves would be collected during their short two

week season, significantly contributing to household earnings, but have since disappeared with forest depletion. The NTFP most widely collected today is jatropha, a drought resistant plant commonly used for bio-diesel production. Although resilient, this plant has extremely negative effects on soil quality.

(121) NTFP Collection Rate="Total Date Palm/Wild Fruits"+Total Gum+Total Honey+Total Tendu Leaves+Total Jatropha
Units: Kg of NTFP/Month

(156) "Total Date Palm/Wild Fruits"="Date Palm/Wild Fruits per HH"*Number of HH
Units: Kg of NTFP/Month

(157) Total Gum=Gum per HH*Number of HH
Units: Kg of NTFP/Month

(158) Total Honey=Honey per HH*Number of HH
Units: Kg of NTFP/Month

(159) Total Jatropha=Jatropha per HH*Number of HH
Units: Kg of NTFP/Month

(160) Total Tendu Leaves=Number of HH*Tendu Leaves per HH
Units: Kg of NTFP/Month

(028) "Date Palm/Wild Fruits per HH"=5.416
Units: Kg of NTFP/Month

(029) "Date Palm/Wild Fruits Price"=0
Units: Rupees/Kg of NTFP

(078) Gum per HH=0
Units: Kg of NTFP/Month

(079) Gum Price=40
Units: Rupees/Kg of NTFP

(083) Honey per HH=0.025
Units: Kg of NTFP/Month

(084) Honey Price=85
Units: Rupees/Kg of NTFP

(098) Jatropha per HH=40/12
Units: Kg of NTFP/Month

(099) Jatropha Price=10
Units: Rupees/Kg of NTFP

(149) Tendu Leaves per HH=0
Units: Kg of NTFP/Month

(150) Tendu Leaves Price=1.99
Units: Rupees/Kg of NTFP

(058) "Fraction DP/WF Sold"=0
Units: Kg/Kg

(059) Fraction Gum Sold=0
Units: Kg/Kg

(060) Fraction Honey Sold=1
Units: Kg/Kg

(061) Fraction Tendu Leaves Sold=1
Units: Kg/Kg

(127) Other Produce Income=(Tendu Leaves per HH*Tendu Leaves Price*Fraction Tendu Leaves Sold)+(Gum per HH*Gum Price*Fraction Gum Sold)+(Honey per HH*Honey Price*Fraction Honey Sold)+("Date Palm/Wild Fruits per HH"*"Date Palm/Wild Fruits Price"*"Fraction DP/WF Sold")+(Jatropha per HH*Jatropha Price)
Units: Rupees/Month

Livestock Income

The total livestock population in the villages has decreased substantially due to deforestation. At one time, a typical household maintained 30-40 cattle. However, lack of fodder and water has led to a significant decrease in livestock population per household. Products from sheep and buffalo, such as guy, are sold at neighboring villages and contribute to a household's income. Production of livestock products greatly depends on animal health, which is greatly impacted by fodder

availability. Households also use livestock dung as fertilizer for crops. Fewer animals results in less dung, making it more difficult to have high yielding agriculture seasons.

(009) Buffalo= INTEG (Buffalo Increase,1)
Units: Head

(010) Buffalo Dung Production Rate=360
Units: Kg of Dung/(Head*Month)

(012) Buffalo Increase=IF THEN ELSE(Maximum Number of Buffalo>Buffalo, IF THEN ELSE(Savings>(Buffalo Price*Head Increment), STEP(8, 1), 0), 0)
Units: Head/Month

(013) Buffalo Milk Production=1
Units: Kg/Month/Head

(014) Buffalo Price=4000
Units: Rupees/Head

(015) Buffalo Products Price=300
Units: Rupees/Kg

(017) Cattle= INTEG (Cattle Increase,1.5)
Units: Head

(018) Cattle Dung Production Rate=210
Units: Kg of Dung/(Month*Head)

(020) Cattle Increase=IF THEN ELSE(Maximum Number of Cattle>Cattle, IF THEN ELSE(Savings>(Cattle Price*Head Increment), STEP(8, 1), 0), 0)
Units: Head/Month

(021) Cattle Price=5000
Units: Rupees/Head

(069) Goat Dung Production Rate=1
Units: Kg of Dung/(Month*Head)

(070) Goat Increase Rate=Goats/Goat Reproduction Time
Units: Head/Month

(072) Goat Price=2500
Units: Rupees/Head

(073) Goat Reproduction Time=24
Units: Months

(074) Goat Sales=Selling Goats
Units: Head/Month

(075) Goats= INTEG (Goat Increase Rate-Selling Goats,7)
Units: Head

(135) Selling Goats=7/24
Units: Head/Month

(136) Selling Sheep=1/24
Units: Head/Month

(137) Sheep= INTEG (Sheep Increase Rate-Selling Sheep,1)
Units: Head

(138) Sheep Dung Production Rate=30
Units: Kg of Dung/(Month*Head)

(140) Sheep Increase Rate=Sheep/Sheep Reproduction Time
Units: Head/Month

(142) Sheep Price=1650
Units: Rupees/Head

(143) Sheep Product Production=1/12
Units: Kg/Month/Head

(144) Sheep Products Price=60
Units: Rupees/Kg

(145) Sheep Products Sold Per Sheep=Sheep*Sheep Product Production
Units: Kg/Month

(146) Sheep Reproduction Time=24
Units: Months

(147) Sheep Sales=Selling Sheep
Units: Head/Month

(103) Livestock Income=(Milk Products Sold Per Buffalo*Buffalo Products Price)+(Sheep Products Sold Per Sheep*Sheep Products Price)+(Sheep Sales*Sheep Price)+(Goat Sales*Goat Price)
Units: Rupees/Month

(117) Milk Products Sold Per Buffalo=Buffalo Milk Production*Buffalo
Units: Kg/Month

(080) Head Increment=1
Units: Head

(114) Maximum Number of Buffalo=3
Units: Head

(115) Maximum Number of Cattle=3
Units: Head

(032) Dung=(Buffalo*Buffalo Dung Production Rate)+(Cattle*Cattle Dung Production Rate)+(Goat Dung Production Rate*Goats)+(Sheep*Sheep Dung Production Rate)
Units: Kg of Dung/Month

Fodder Demand

Conservation Efforts: Community Charagahs

Charagahs are common pasturelands and forests that provide natural resources to community members. These charagahs are a principal source of fodder for livestock; animals freely graze these pasturelands year-round. However, nearly 40% of these communal resources are barren and ineffective due to over-extraction and poor environmental conditions. Managed by village panchayats, community members frequently use these areas that are critical to their livelihoods, but often neglect and deny responsibility for the condition of these lands. This view results in abuse and overuse of charagahs. Excessive grazing inhibits fodder regeneration, and overcutting trees and shrubs causes soil erosion. The condition of these mismanaged community lands significantly affects amounts of fodder extraction from the sanctuary. It has been observed that the more fertile charagah lands available, the less the village members will have to resort to extracting natural resources, most notably fodder, from the sanctuary.

Conservation Efforts: Joint Forest Management Protected Plots

Joint Forest Management (JFM) protected plots were created to alleviate pressure on the sanctuary as well as meet livelihood requirements of local people. These areas are governed by combined efforts from local communities and state forest departments. Agreements between the people and the government allow the local people to become involved in conservation efforts and become aware of conservation concepts. JFMs also provide additional labor opportunities and as well as fodder and NTFP resources, helping contribute to villagers' livelihoods.

(011) Buffalo Fodder Demand=120
Units: Kg of fodder/(Month*Head)

(019) Cattle Fodder Demand=780
Units: Kg of fodder/(Month*Head)

(071) Goat Leafy Fodder Demand=300
Units: Kg of fodder/(Month*Head)

(139) Sheep Fodder Demand=30
Units: Kg of fodder/(Month*Head)

(141) Sheep Leafy Fodder Demand=60-Sheep Fodder Demand
Units: Kg of fodder/(Head*Month)

(049) Feed Processed per Kg Wood=1
Units: Kg of fodder/Kg of Wood

(050) Feed Processing Energy Demand=Processed Feed/Feed Processed per Kg Wood
Units: Kg of Wood/Month

(052) Fodder Collection Rate=Grazing Within Sanctuary+Leafy Fodder Demand
Units: Kg of fodder/Month

(056) Fodder Produced on Private Lands=Effect of Rainfall on Fodder Growth(Yearly Rainfall/Initial Yearly Rainfall)*Max Private Lands Fodder
Units: Kg of fodder/Month

(023) Community Charagahs=Effect of Rainfall on Fodder Growth(Yearly Rainfall/Initial Yearly Rainfall)*Max Charagah Fodder
Units: Kg of fodder/Month

(076) Grassy Fodder Demand=Buffalo*Buffalo Fodder Demand+Cattle*Cattle Fodder Demand+Sheep*Sheep Fodder Demand
Units: Kg of fodder/Month

(077) Grazing Within Sanctuary=IF THEN ELSE(Stall Feeding<Grassy Fodder Demand, Grassy Fodder Demand-Stall Feeding, 0)
Units: Kg of fodder/Month

(102) Leafy Fodder Demand=(Goats*Goat Leafy Fodder Demand)+(Sheep*Sheep Leafy Fodder Demand)
Units: Kg of fodder/Month

(131) Processed Feed=Maize Crop Residue Available
Units: Kg of fodder/Month

(045) Effect of Rainfall on Fodder Growth([(0,0)-(3000,1)],(0,0),(500,0.3333),(1000,0.6666),(1500,1),(1752.29,0.942982),(1908.26,0.820175),(2073.39,0.425439),(2348.62,0.166667),(3000,0))
Units: mm/mm

(108) Max Charagah Fodder=0.6*1700/12
Units: Kg of fodder/Month

(109) Max JFM Fodder=0.4*1700/12
Units: Kg of fodder/Month

(110) Max Private Lands Fodder=300/12
Units: Kg of fodder/Month

(100) JFM Protected Forest Plots=Effect of Rainfall on Fodder Growth(Yearly Rainfall/Initial Yearly Rainfall)*Max JFM Fodder
Units: Kg of fodder/Month

(148) Stall Feeding=Community Charagahs+Fodder Produced on Private Lands+JFM Protected Forest Plots+Processed Feed
Units: Kg of fodder/Month

Agriculture

The combination of agricultural productivity decline and human population increase has amplified the need for farmlands, which are often created by clearing of conserved areas. Maize is most commonly grown, with wheat as a second rotational crop in years with ample water resources. Maize crop serves as a staple food source, and crop residue is used and processed for animal fodder. In years where agricultural yield fails to meet food demand, a household must resort to purchasing food, which increases expenditures. In order to prevent deficit, households turn to other income sources, many of which involve extraction of sanctuary products. Agricultural yield is a sensitive variable changing from year to year that has the potential to cause cascading effects on a household's income and livelihood state.

(001) Agricultural Expenditures= (Food Demand per HH-(Maize Produce+Wheat Produce))*Agricultural Food Price
Units: Rupees/Month

(002) Agricultural Food Price=8
Units: Rupees/Kg of Ag

(105) Maize Crop Residue per Maize Produce=0.0625
Units: Kg of fodder/Kg of Ag

(057) Food Demand per HH=90
Units: Kg of Ag/Month

(003) Agricultural Land Area=1.5
Units: Bigah

(004) Agricultural Yield=Effect of Dung on Agricultural Yield(Dung/Initial Dung)*Effect of Rainfall on Agricultural Yield(Yearly Rainfall/Initial Yearly Rainfall)*Maximum Agricultural Productivity
Units: Kg of Ag/Bigah/Month

(044) Effect of Rainfall on Agricultural Yield([(0,0)-(1200,1)],(0,0),(300,0),(365.138,0.486842),(425.688,0.776316),(484.404,0.929825),(528.44,0.964912),(600,1),(675.229,0.991228),(704.587,0.938596),(748.624,0.833333),(807.339,0.688596),(855.046,0.583333),(900,0.5),(1060.55,0.210526),(1200,0))
Units: mm/mm

(096) Initial Yearly Rainfall=1
Units: mm/Month

(104) Maize Crop Residue Available=Maize Produce*Maize Crop Residue per Maize Produce
Units: Kg of fodder/Month

(091) Initial Dung=1
Units: Kg of Dung/Month

(031) Dry Season Water Availability=IF THEN ELSE(Yearly Rainfall>600, 1, 0)
Units: Yesno

(038) Effect of Dung on Agricultural Yield([(0,0)-(5400,1)],(0,0.5),(450,0.75),(900,1),(1350,1),(1800,1),(2250,1),(3600,1),(4050,1),(4500,1),(4950,1),(5400,1))
Units: Kg/Kg

(106) Maize Produce=Agricultural Land Area*Agricultural Yield
Units: Kg of Ag/Month

(111) Maximum Agricultural Productivity=32
Units: Kg of Ag/(Month*Bigah)

(163) Yearly Rainfall=650
Units: mm/Month

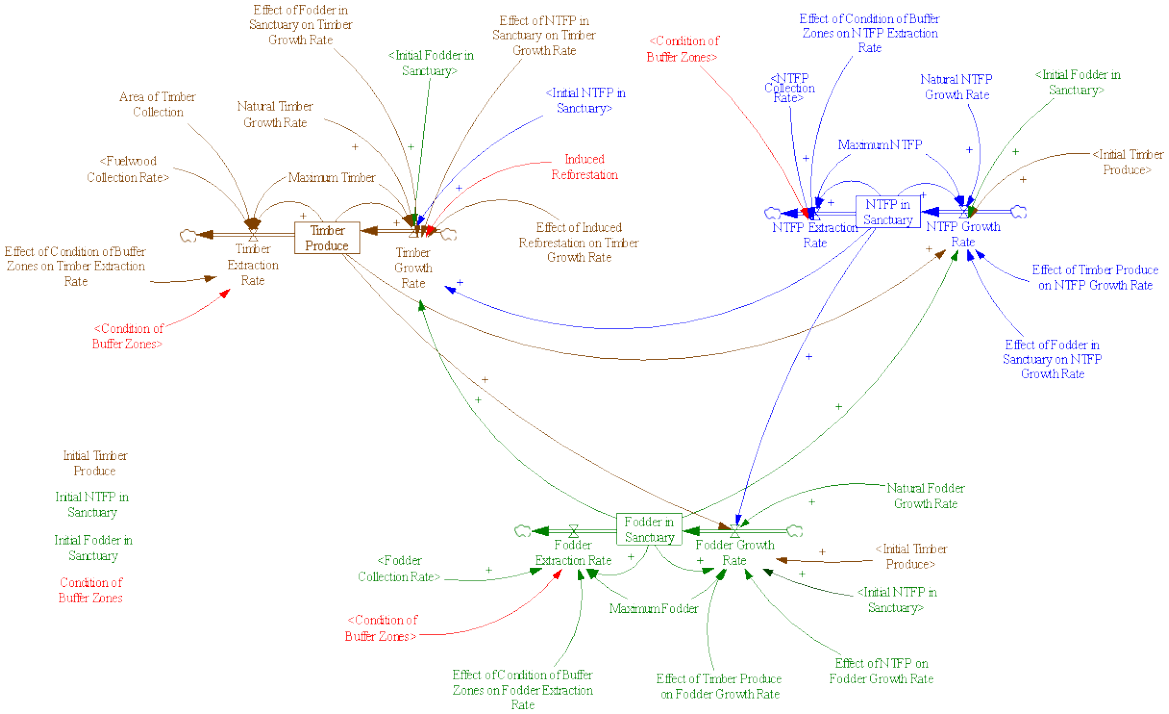
(162) Wheat Produce=IF THEN ELSE(Dry Season Water Availability=1, Agricultural Land Area*0.2*Agricultural Yield, 0)
Units: Kg of Ag/Month

State of the Sanctuary

Evaluation of the overall health of the sanctuary requires observation of multiple factors. Forest density data alone is not an accurate sole indicator of the state of the sanctuary because other crucial factors such as regeneration rate cannot be construed. A few common indicators of sanctuary health include regeneration rate, seed germination, grass cover, forest density, species type, stage of species, seed viability, and food chain balance, which all interlinked and affect one another. Gathered field data affords a selection of these indicators, which affect the interconnected states of timber produce, NTFP, and fodder in the sanctuary.

The complex relationships between mass of Timber Produce, NTFP, and Fodder in the sanctuary all impact one another, as illustrated in the model below.

Figure 29: Sanctuary State



Sanctuary Timber

The raw amount of mass of timber produce in the sanctuary is affected by many variables, including presence of other forest products such as NTFP and fodder. Types of plants in the forest affect the growth rates of each other, as they compete for ground space, sunlight, nutrients, and other essential resources. Multiple species also reinforce the growth of each other, providing nutrients and attracting wildlife to help complete a flourishing ecosystem cycle. Increased amounts of fodder in the sanctuary slow the timber growth rate. However, higher amounts of NTFP in the sanctuary stimulate timber growth rates. As NTFP is extracted from the forest, timber growth rates will accordingly suffer. Although timber can be classified as a single product type and net timber mass typically serves as an accurate measurement of forest health, the presence of favorable and unfavorable trees, as well as observation of diverse classes of species also serve as effective indicators.

Figure 30: Effect of Fodder in Sanctuary on Timber Growth Rate

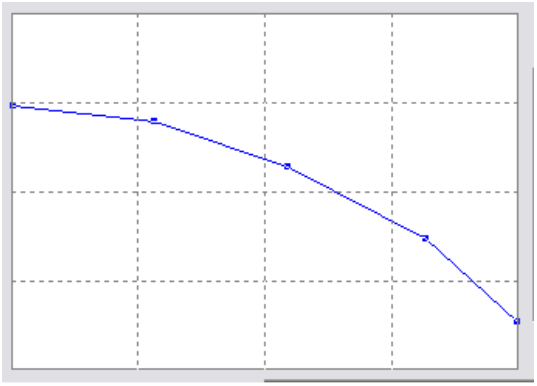
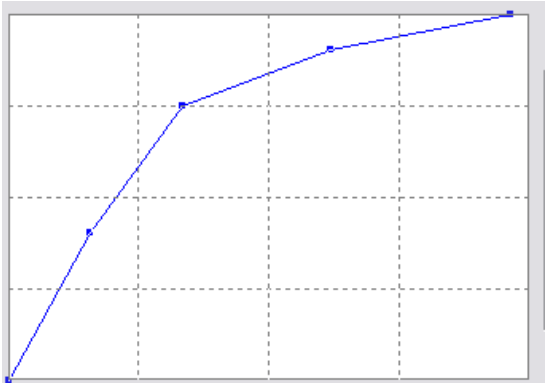


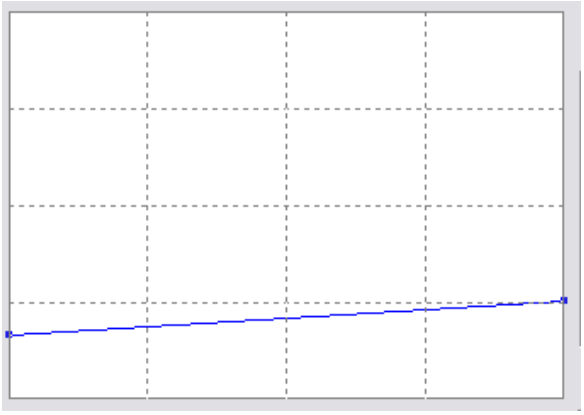
Figure 31: Effect of NTFP in Sanctuary on Timber Growth Rate



Conservation Efforts: Reforestation

The Foundation for Ecological Security (FES) has led a great reforestation effort to plant saplings and seeds of indigenous species both in the sanctuary and surrounding buffer zones. Although these reforestation actions have contributed to forest sustainment, because the rate of biomass extraction exceeds reforestation rates, the current planting activities do not have the capability to counterweigh forest product withdrawal.

Figure 32: Effect of Induced Reforestation on Timber Growth Rate



Buffer Zones

Designated protected areas surrounding the border of the sanctuary alleviate pressure on the sanctuary. The presence of these clearly marked buffer zones has significant impact on the degradation rate of the forest. Typically enclosed by short stone walls to designate boundaries and prevent encroachment, these areas serve as cushions to reduce the negative impacts that the increasing population has on the sanctuary. By providing distinct regions to separate the sanctuary and the village lands, the presence of buffer zones decreases extraction of sanctuary materials.

Figure 33: Effect of Condition of Buffer Zones on Fodder Extraction Rate

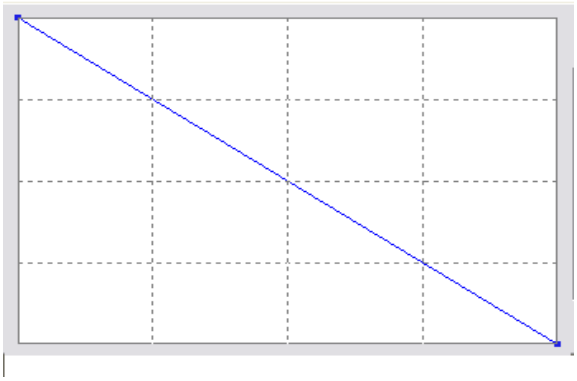


Figure 34: Effect of Condition of Buffer Zones on NTFP Extraction Rate

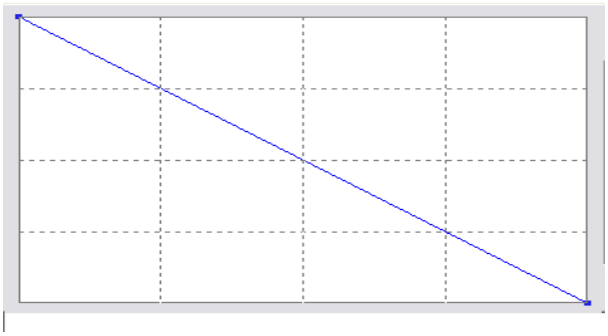
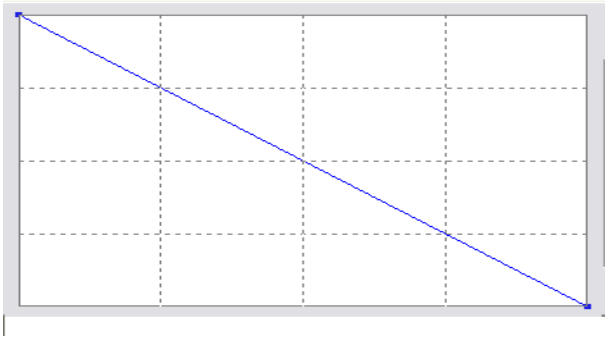


Figure 35: Effect of Condition of Buffer Zones on Timber Extraction Rate



(035) Effect of Condition of Buffer Zones on Timber Extraction Rate([(0,0)-(10,10)],(0,1),(1,0))
Units: Kg/Kg

(041) Effect of Induced Reforestation on Timber Growth Rate([(0,0)-(100,10)],(0,1),(1,1.1))
Units: Kg/Kg

(042) Effect of NTFP in Sanctuary on Timber Growth Rate([(0,0)-(10,10)],(0.0001,0),(1.59021,1.6),(3.36391,3),(6.20795,3.6),(9.63303,4))
Units: Kg/Kg

(040) Effect of Fodder in Sanctuary on Timber Growth Rate([(0,0)(10,10)],(0.030581,4.43),(2.53823,4.16),(4.92355,3.4),(7.37003,2.2),(8.99083,0.8))
Units: Kg/Kg

(024) Condition of Buffer Zones=0.5
Units: Kg/Kg

(007) Area of Timber Collection=60
Units: Bigah

(087) Induced Reforestation=0.5
Units: Kg/Kg

(094) Initial Timber Produce=15000
Units: Kg of Wood/Bigah

(116) Maximum Timber=15000
Units: Kg of Wood/Bigah

(120) Natural Timber Growth Rate=(1+(0.02/12))
Units: 1/Month

(151) Timber Extraction Rate=Effect of Condition of Buffer Zones on Timber Extraction Rate(Condition of Buffer Zones)*Fuelwood Collection Rate*Timber Produce/(Maximum Timber*Area of Timber Collection)
Units: Kg of Wood/(Month*Bigah)

(153) Timber Produce= INTEG (Timber Growth Rate-Timber Extraction Rate,Initial Timber Produce)
Units: Kg of Wood/Bigah

(152) Timber Growth Rate=Natural Timber Growth Rate*((Maximum Timber-Timber Produce)/Maximum Timber)*Effect of NTFP in Sanctuary on Timber Growth Rate(NTFP in Sanctuary/Initial NTFP in Sanctuary)*Effect of Fodder in Sanctuary on Timber Growth Rate(Fodder in Sanctuary/Initial Fodder in Sanctuary)*Effect of Induced Reforestation on Timber Growth Rate(Induced Reforestation)
Units: Kg of Wood/Bigah/Month

Sanctuary NTFP

NTFP is a crucial part of the forest ecosystem, supplying diverse products for wildlife and other plants alike. These forest commodities from the Kumbhalgarh sanctuary include date palm, wild fruits, honey, gum, tendu leaves, and jatropha, and when present, are collected by people in the nearby communities. These products directly contribute to the livelihoods of the people; some are directly used by households in the community and others are sold or traded at nearby markets. As the forest depletes, less NTFP is produced, directly affecting critical livelihood resources. The amounts of NTFP present in the sanctuary are affected by multiple factors, most notably the amounts of fodder and timber coexisting in the forest. Increased fodder in the sanctuary slows the NTFP growth rate. Fodder and NTFP compete for nutrients and ground space. Aggressive grasses and shrubs can suffocate and oust NTFP plants. The presence of timber produce positively affects NTFP growth rate; as the amount of timber produce increases, so does NTFP growth proportionally increases as well. As timber is extracted from the forest for fuelwood, NTFP forest product growth slows.

Figure 36: Effect of Fodder in Sanctuary on NTFP Growth Rate

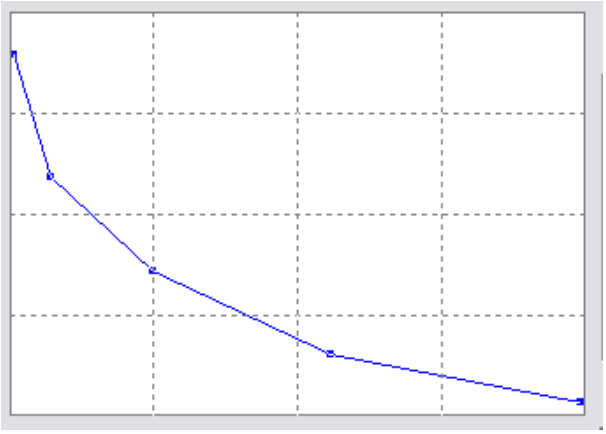
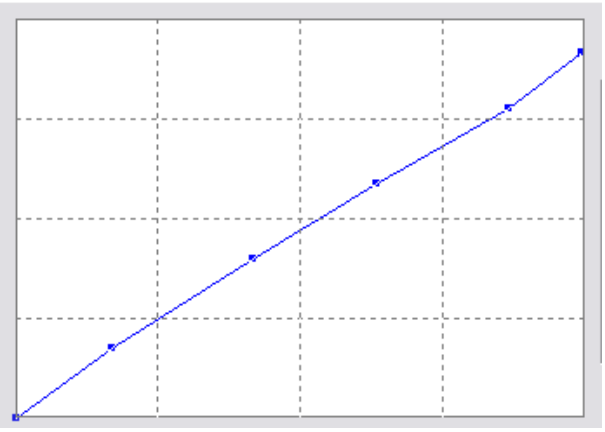


Figure 37: Effect of Timber Produce on NTFP Growth Rate



(006) Area of NTFP Collection=1
Units: Bigah

(034) Effect of Condition of Buffer Zones on NTFP Extraction Rate([(0,0)-(10,10)],(0,1),(1,0))
Units: Kg/Kg

(039) Effect of Fodder in Sanctuary on NTFP Growth Rate([(0,0)(10,10)],(0.0611621,8.90351),(0.642202,5.92105),(2.23242,3.59649),(5.01529,1.49123),(8.92966,0.307018))
Units: Kg/Kg

(047) Effect of Timber Produce on NTFP Growth Rate([(0,0)-(10,10)],(0.0001,0),(1.52905,1.71053),(3.76147,3.94737),(5.71865,5.87719),(7.79817,7.7193),(8.96024,9.12281))
Units: Kg/Kg

(093) Initial NTFP in Sanctuary=1610
Units: Kg of NTFP/Bigah

(113) Maximum NTFP=1610
Units: Kg of NTFP/Bigah

(119) Natural NTFP Growth Rate=(1+(0.05/12))
Units: 1/Month

(122) NTFP Extraction Rate=Effect of Condition of Buffer Zones on NTFP Extraction Rate(Condition of Buffer Zones)*NTFP Collection Rate*NTFP in Sanctuary/(Maximum NTFP*Area of NTFP Collection)
Units: Kg of NTFP/(Month*Bigah)

(123) NTFP Growth Rate=Natural NTFP Growth Rate*((Maximum NTFP-NTFP in Sanctuary)/Maximum NTFP)*Effect of Timber Produce on NTFP Growth Rate(Timber Produce/Initial Timber Produce)*Effect of Fodder in Sanctuary on NTFP Growth Rate(Fodder in Sanctuary/Initial Fodder in Sanctuary)
Units: Kg of NTFP/(Month*Bigah)

(124) NTFP in Sanctuary= INTEG (NTFP Growth Rate-NTFP Extraction Rate,Initial NTFP in Sanctuary)
Units: Kg of NTFP/Bigah

Sanctuary Fodder

Fodder availability is critical for managing livestock, which is a key contributor to livelihood. Households obtain fodder from crop residue, JFM forested plots, community charagahs, and private lands, in addition to collecting fodder from the sanctuary. Local people collectively protect defined areas to meet their own fodder requirement during the summer seasons, but allow livestock to roam freely within the federal boundaries during the rest of the year. Households send livestock, mainly buffalo and sheep, to graze the sanctuary for grassy fodder. Sheep roam the forested lands for grassy and leafy fodder, and goats consume only leafy fodder. Typically, livestock roam the forests during the day hours and are stall fed each night. Excessive grazing of these sanctuary lands over time causes the forest resources to deplete, which hinders the forest's ability to recover and grow. Presence of NTFP has positive effects on fodder growth rate, but only up to a certain point. NTFP provides soil nutrients, attracts wildlife, and contributes to the overall state of the forest ecosystem, which in turn, affects fodder growth. At this stage, extraction of NTFP slows the fodder growth rate, directly providing NTFP, but reducing future fodder resources. If too much NTFP is present, fodder will not have room to grow and flourish in the limited grounds space in the forest. Similarly, as timber produce increases, fodder growth decreases. An increased presence of trees will limit the amount of sunlight on the forest floor, impeding grassy fodder growth.

Figure 38: Effect of NTFP on Fodder Growth Rate

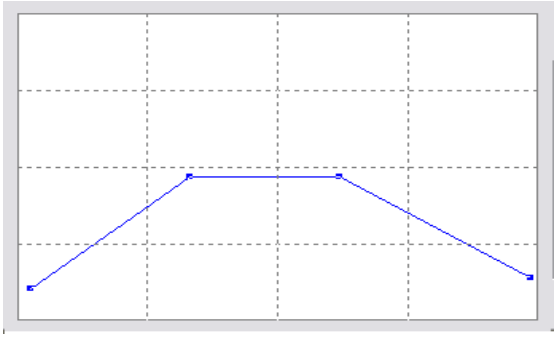


Figure 39: Effect of Timber Produce on Fodder Growth

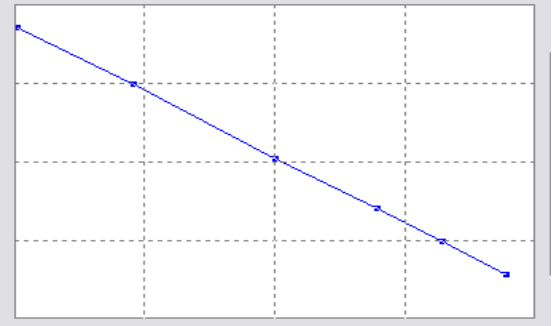
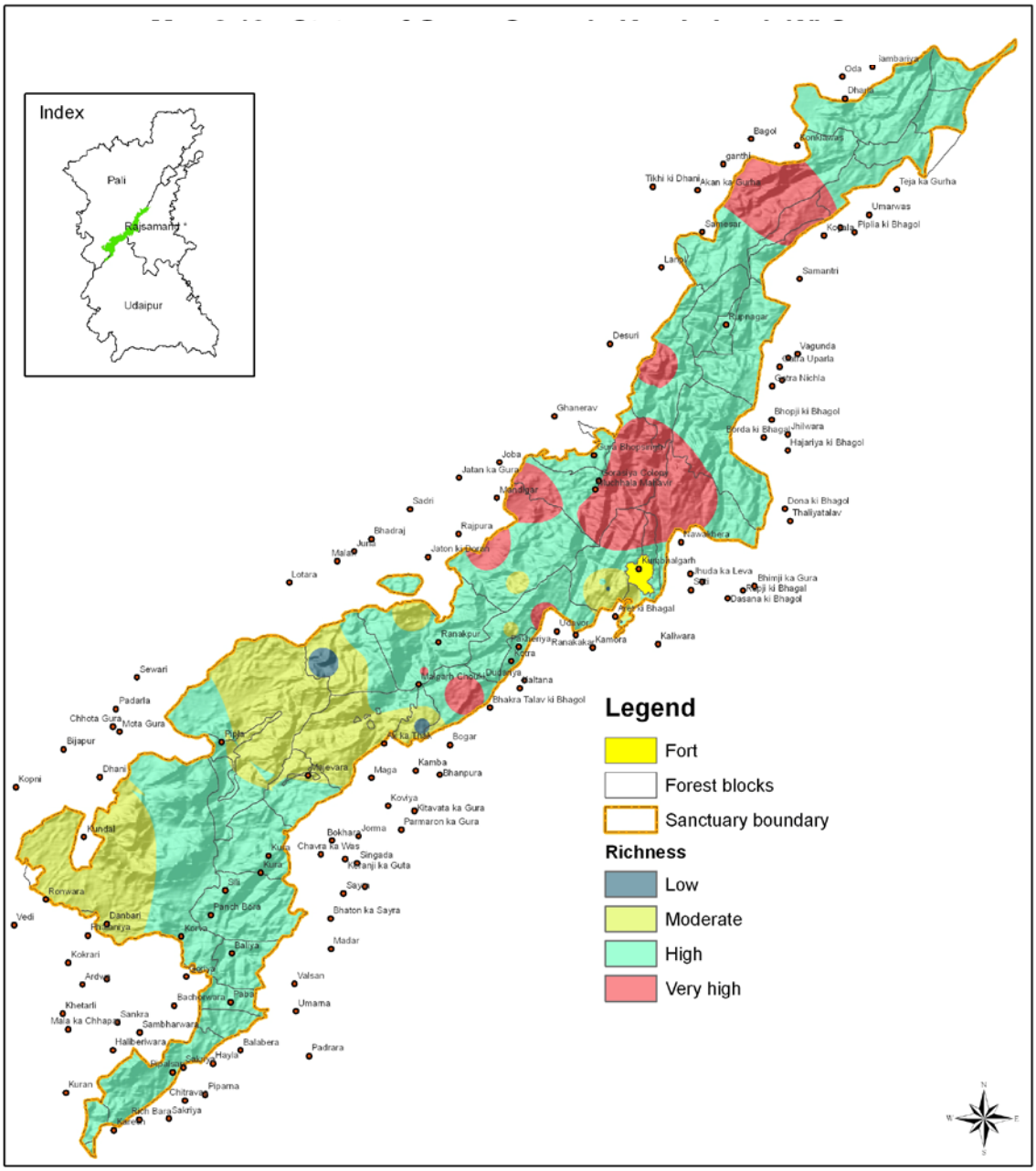


Figure 40: Grass Cover in Kumbhalgarh Wildlife Sanctuary



(005) Area of Fodder Collection=1
Units: Bigah

(033) Effect of Condition of Buffer Zones on Fodder Extraction Rate([(0,0)-(10,10)],(0,1),(1,0))
Units: Kg/Kg

(043) Effect of NTFP on Fodder Growth Rate([(0,0)-(10,10)],(0.58104,0.921053),(1.49847,1.35965),(2.35474,1.35965),(3.45566,0.964912))
Units: Kg/Kg

(046) Effect of Timber Produce on Fodder Growth Rate([(0,0)-(10,10)],(0.0611621,9.21053),(2.29358,7.45614),(5.04587,5.04386),(6.97248,3.50877),(8.25688,2.45614),(9.48012,1.35965))
Units: Kg/Kg

(053) Fodder Extraction Rate=Effect of Condition of Buffer Zones on Fodder Extraction Rate(Condition of Buffer Zones)*Fodder Collection Rate*Fodder in Sanctuary/(Maximum Fodder*Area of Fodder Collection)
Units: Kg of fodder/(Bigah*Month)

(054) Fodder Growth Rate=Natural Fodder Growth Rate*((Maximum Fodder-Fodder in Sanctuary)/Maximum Fodder)*Effect of NTFP on Fodder Growth Rate(NTFP in Sanctuary/Initial NTFP in Sanctuary)*Effect of Timber Produce on Fodder Growth Rate(Timber Produce/Initial Timber Produce)
Units: Kg of fodder/(Month*Bigah)

(055) Fodder in Sanctuary= INTEG (Fodder Growth Rate-Fodder Extraction Rate,Initial Fodder in Sanctuary)
Units: Kg of fodder/Bigah

(092) Initial Fodder in Sanctuary=200
Units: Kg of fodder/Bigah

(112) Maximum Fodder=200
Units: Kg of fodder/Bigah

(118) Natural Fodder Growth Rate=(1+(0.23/12))
Units: 1/Month

Population

(125) Number of HH=Population/People per HH
Units: person/person

(129) People per HH=8
Units: person

(130) Population=805
Units: person

Miscellaneous

(051) FINAL TIME = 100
Units: Month
The final time for the simulation.

(095) INITIAL TIME = 0
Units: Month
The initial time for the simulation.

(132) SAVEPER = TIME STEP
Units: Month [0,?]
The frequency with which output is stored.

(154) TIME STEP = 0.125
Units: Month [0,?]
The time step for the simulation.