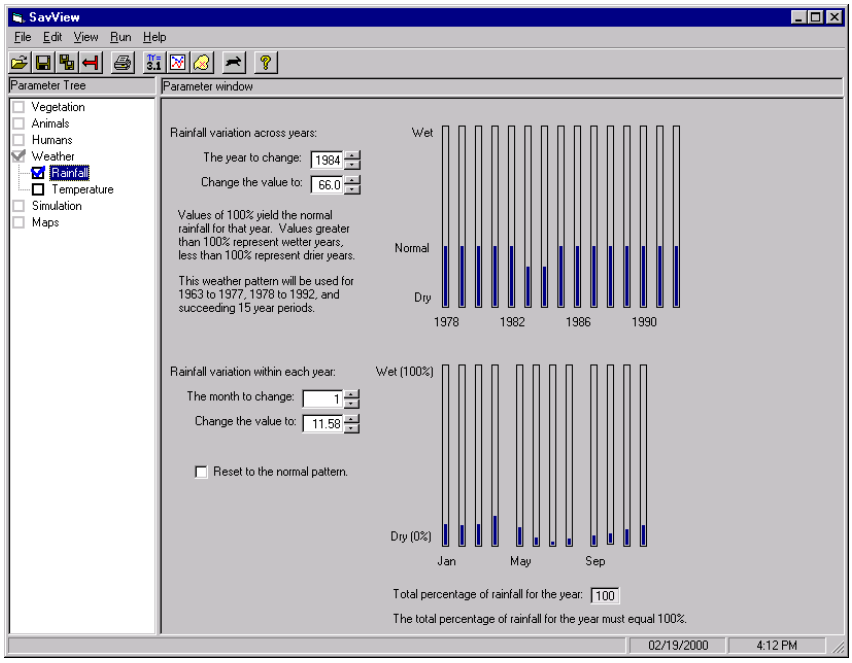
Experiments addressing Potential Management Questions

Experiments - Effects of Drought

The semi-arid areas of East Africa are susceptible to moderate to severe droughts. Ecosystem responses to drought can be complex in Ngorongoro Conservation Area, because of its location and topography. NCA includes some of the driest portions of the Greater Serengeti Ecosystem (450 mm per year rainfall in the shadow of Ngorongoro Crater) to moist tropical forests within the Northern Forest Highland Reserve (more than 1150 mm rainfall per year). Savanna can suggest how the ecosystem might respond to drought.

SavView allows rainfall across years to be modified, from no rain at all to three times normal rainfall for months with rain (although the model has not been tested under such extremes!). In the program, rainfall is simply adjusted by multiplying the normal rainfall for each month in the year adjusted by the percentage given. With this method, months with zero rainfall will remain with zero rainfall, and wetter months will change proportional to the value entered.

To change rainfall amounts across years, enter the "Parameter" section of SavView, click upon "Weather" and "Rainfall", and adjust the rainfall in the top chart for the years of interest.



In the example shown, rainfall for 1983 and 1984 have been reduced by one-half. Note that these years were dry in reality, so the drought induced is somewhat more extreme than the one-half reduction in rainfall suggests.

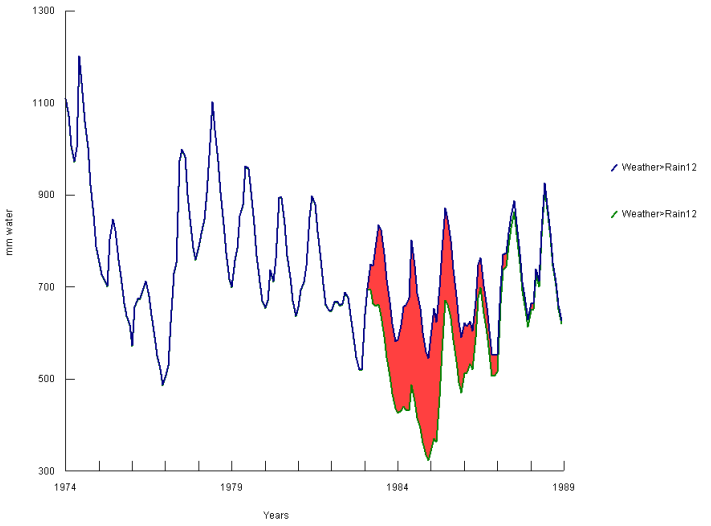
Exercise: Using SavView reduce rainfall in 1983 and 1984 by 50%, and keeping all other values at their original settings, and run Savanna. After the model completes, compare the changes in plants and animals in response to a two-year drought.

Notes: This simulation may take as much as an hour to complete, depending upon the speed of the computer. A completed analysis is stored upon the accompanying CD disc. Note that a similar experiment was done using NCA-Savanna 4E.1, but in that case, rainfall in 1983 and 1984 (in a simulation from 1974 to 1988) was adjusted using special programs. In that case, adjusting rainfall for 1983 entailed adjusting rainfall for November 1982 to October 1983, for example.

Experiments - Effects of Drought (continued)

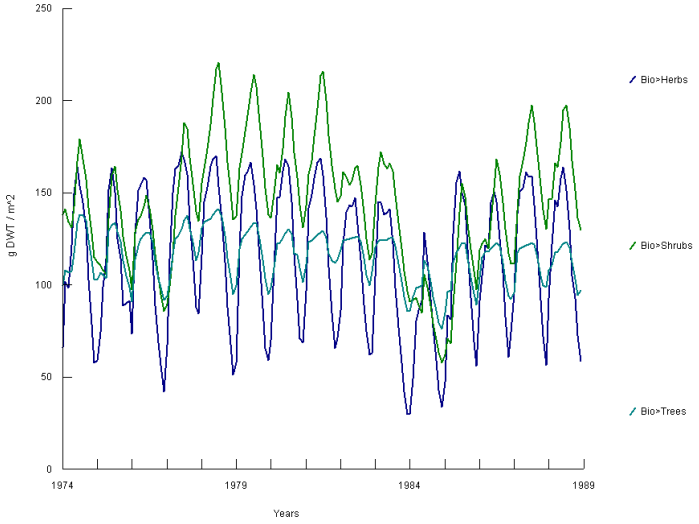
The change in rainfall occurring from setting 1983 and 1984 at 50% normal rainfall

Rainfall was decreased by 50% for the years 1983 and 1984.

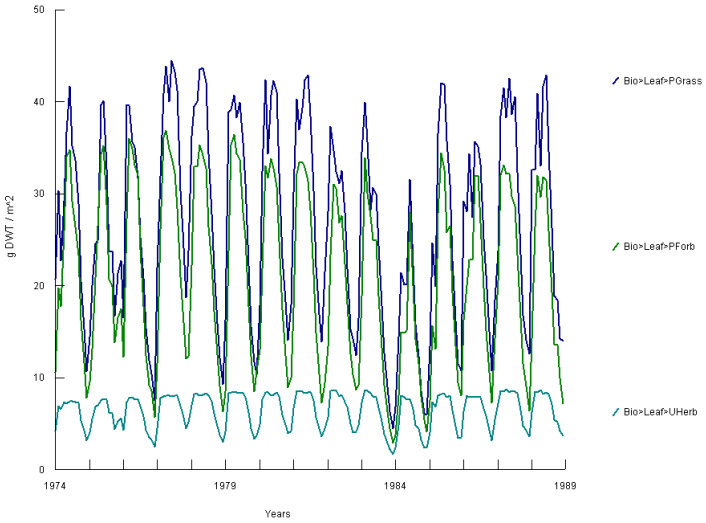


Total biomass , by plant groups

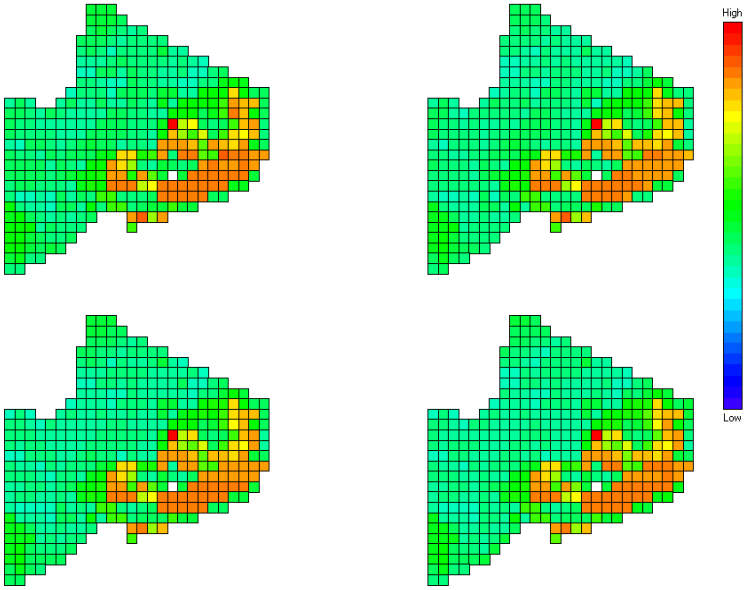
The total green biomass for all groups declined during and following the drought. However, grasses and trees recovered more quickly from the drought than did shrubs.



Green leave biomass for herbaceous plants



Total green leaf biomass for January through April in a year of drought, 1984

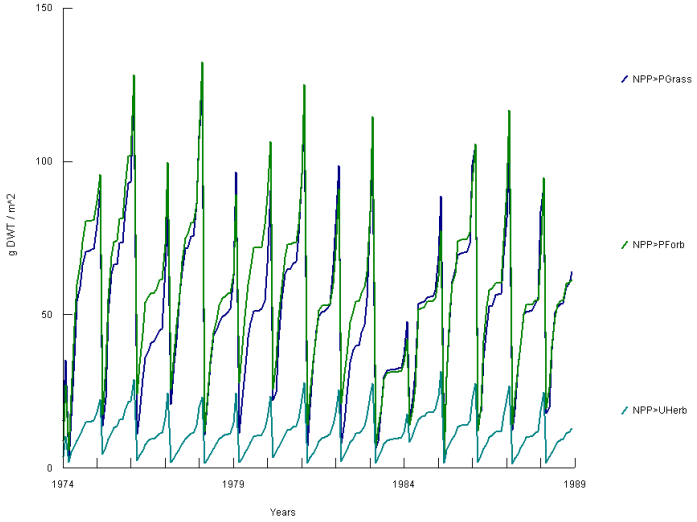


A decline in forage availability and in total green biomass is shown spatially as well. In what should be the peak greenness dates, total green biomass is relatively low for all of Ngorongoro, with few bright red squares shown.

Experiments - Effects of Drought (continued)

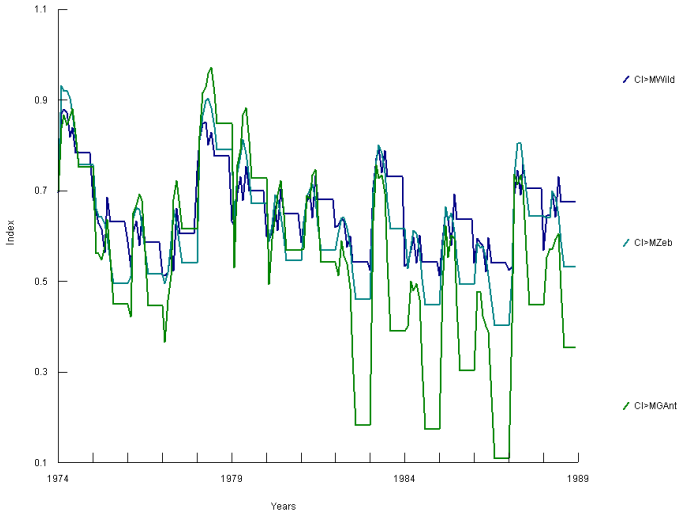
Accumulated net primary productivity

A sharp decline in productivity by plants is seen during the drought years of 1983 and 1984.

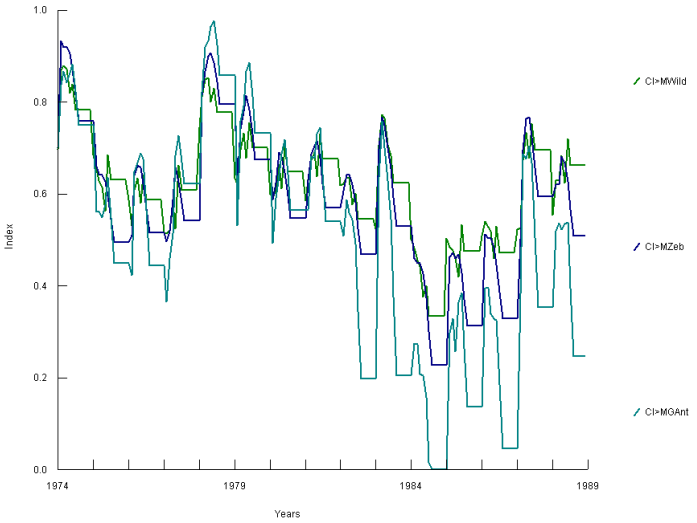


***Control model** condition indices for migratory animal groups (wildebeest, zebra, and grazing antelope)*

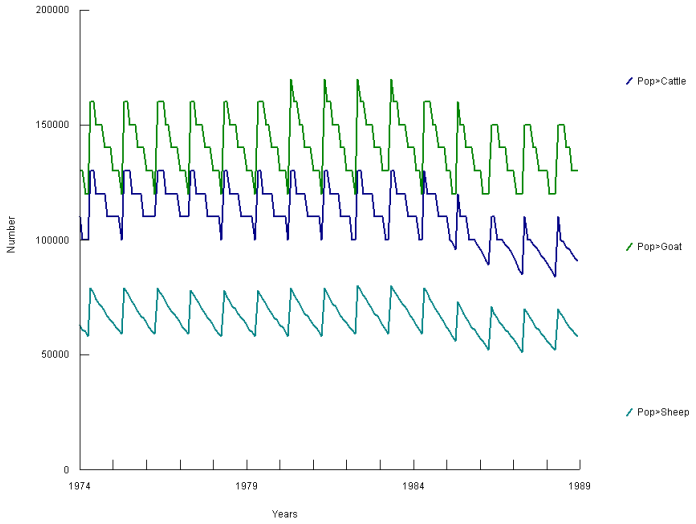
Populations of migratory animals will not change in NCA-Savanna, but a decline in their overall condition indices during drought is evident.



Condition indices for migratory animals with the 1983-1984 drought in place.



Livestock populations



Livestock decline in response to drought, with cattle showing a somewhat stronger response. In general, however, the response of livestock to drought in NCA-Savanna is not as severe as might be expected. This is because the livestock populations are modeled below the carrying capacity of the system, with populations reduced by disease. Therefore some forage remains unused, and if killed in drought, it will not effect livestock.

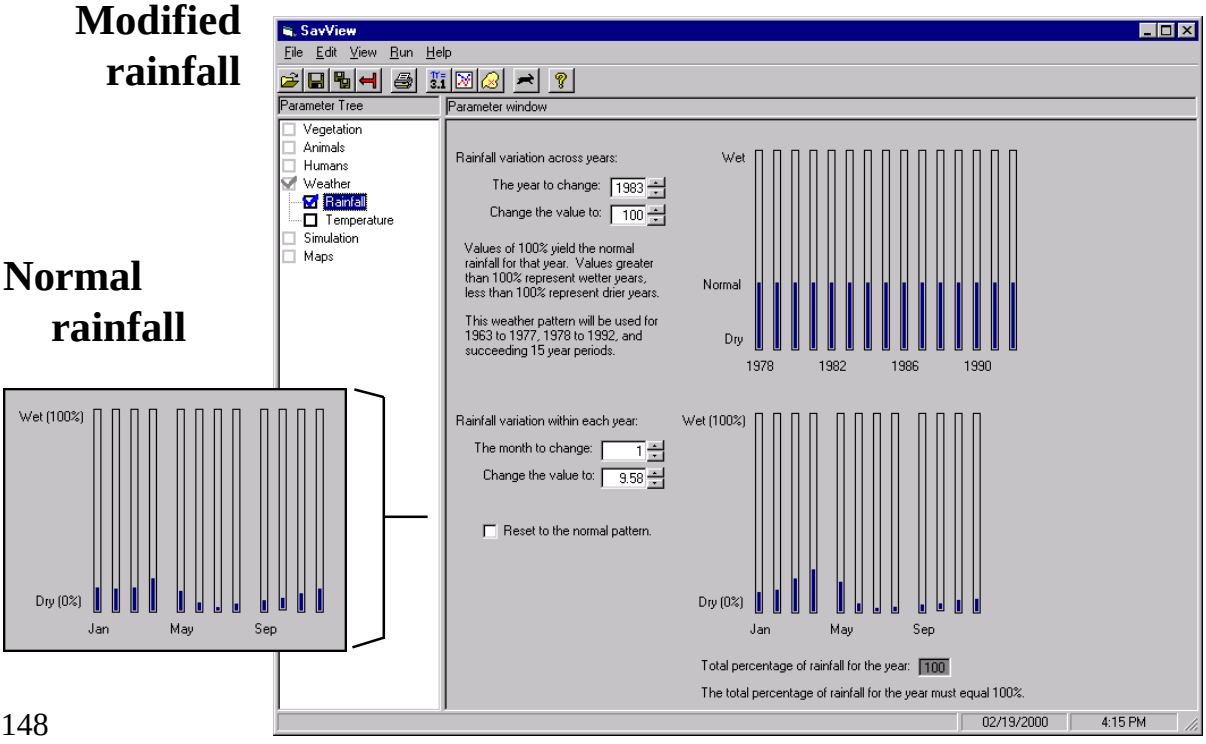
Experiments - Rainfall within Years

Evidence suggests that the amount of rainfall within a given year is not the only important thing affecting of production in East African semi-arid regions. The distribution of rainfall throughout the year is important as well. Rainfall falling all within a short period may lead to high productivity (and flooding), but if it is followed by an extended dry period, livestock and wildlife will suffer. In contrast, if a given amount of rainfall is spread more evenly throughout the year, plant production and animal condition can remain high.

You may change the distribution of rainfall throughout the year in SavView, to explore possible ecosystem responses to such changes. By default, the normal pattern of rainfall is shown in the "Rainfall" window of the parameter set. The lower graph shows how the rainfall in NCA is distributed across months, as a portion of 100%. You may change this distribution. All the years in the weather file will be adjusted to match your request as much as possible.

Modified rainfall

Normal rainfall



When distributing rainfall for the year, the total rainfall is summed, then distributed across years with valid rainfall data, in proportion to the pattern that is selected in the “Rainfall” parameter window.

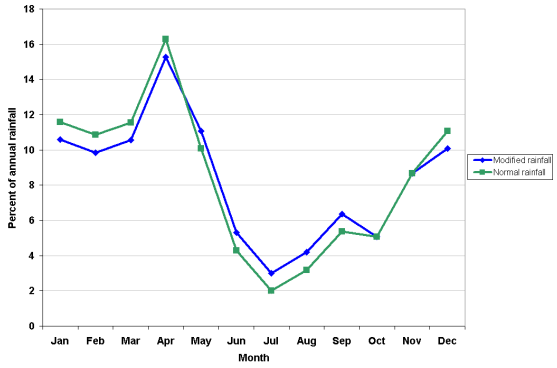
Exercise: Using SavView, adjust the distribution of rainfall within the year similar to that illustrated on the previous page. Please do not run Savanna at this time, however - we will review the results of this experiment as a group.

Notes: The change described will be applied to all the years in the simulation, to keep SavView from being overly complex. If you wish to modify only some years, make the change as described and select “Run” in SavView, but cancel the run after SavView saves the changes you have made. Then in a text editor, create a new precipitation file in the Savanna “parms” directory by merging the NEW6392.MRG you have created and the original PPT6392.MRG, and editing SIMCON.PRM to read the new file.

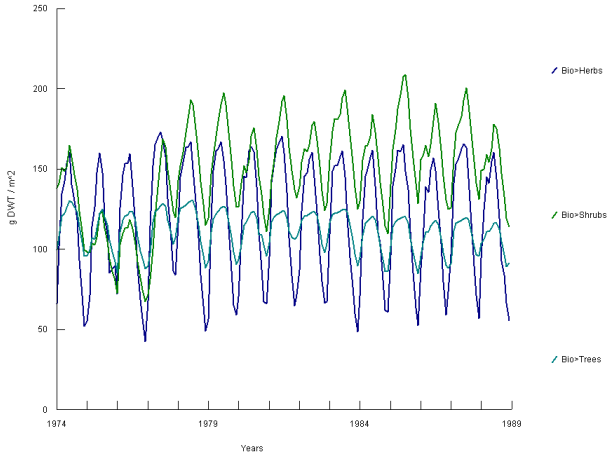
Experiments - Rainfall within Years (continued)

Here, rainfall has been adjusted to reduce rainfall by 1% during the wetter months (December, January, February, March, and April) and 1% rainfall added to the drier months (May, June, July, August, September). This involves adjusting the rainfall for each weather station for each year, removing the normal variability in rainfall across months. Because of that, a separate control run was made, with the rainfall adjusted for each month, so that it matched the normal pattern in Ngorongoro.

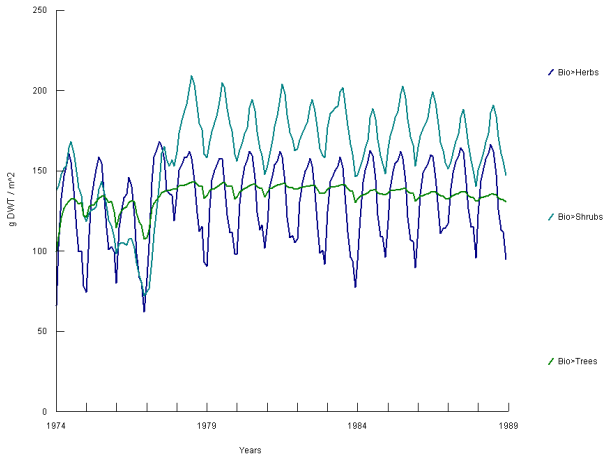
Normal and modified rainfall distribution in Ngorongoro



Under normal rainfall patterns biomass drops below 70 g/m^2, for herbs, and shrubs and trees show similar declines.

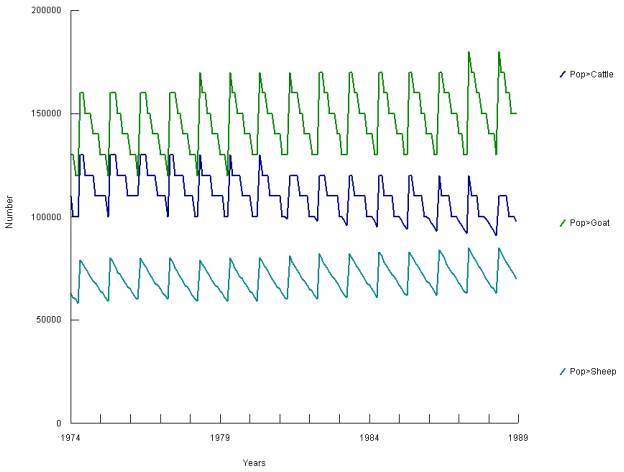


With the distribution of rain more evenly spread, herb biomass stays greater than 90 g/m^2, in general, and shrubs and trees retain leaves.



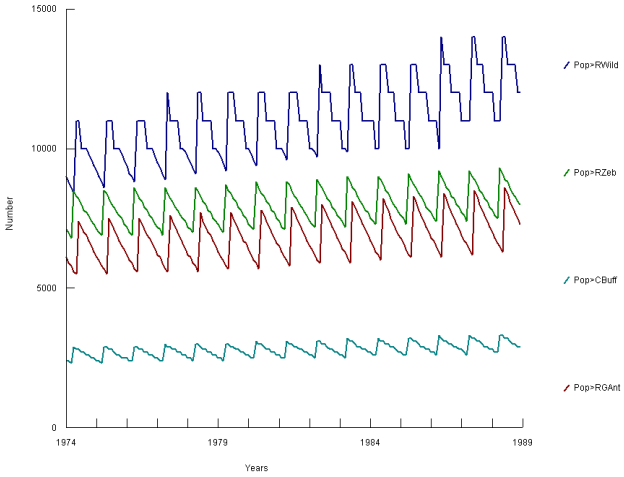
Livestock populations

Livestock stay the same or increase in response to increased forage in the dry season. Livestock do not increase as strongly as wildlife because deaths due to disease increase in wet months.



Wildlife populations (with selected grazers shown)

Wildlife increase markedly in response to having rainfall more evenly distributed throughout the year.



Experiments - More Livestock

Livestock numbers in the Ngorongoro Conservation Area have been fairly constant for over recent decades (although there have been changes in the ratio of goats and sheep to cattle). That said, the number of people in the area is increasing, so that each household owns fewer livestock. Ongoing projects and proposals may increase the numbers of livestock in NCA. Savanna can suggest what the benefits to households would be from increased livestock holdings, and changes in the ecosystem.

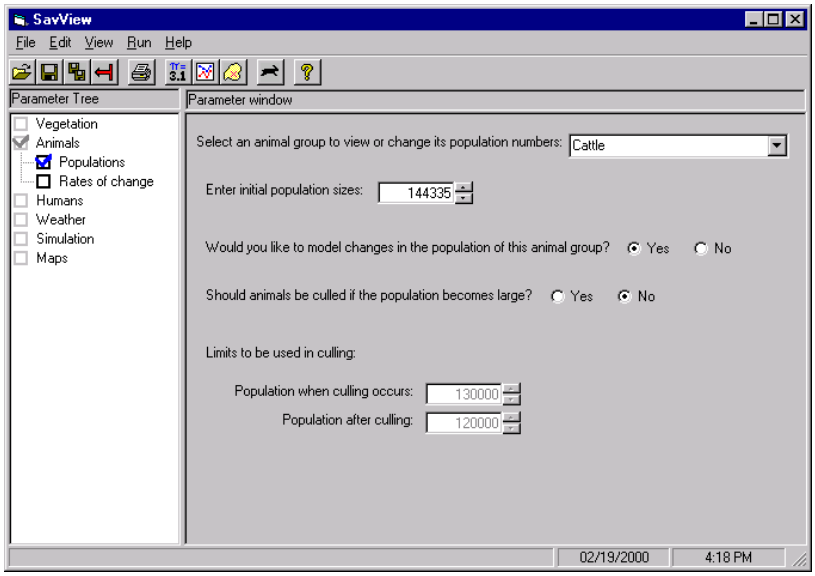
We will discuss three ways of modeling an increase in animal populations, and carry-through with one of the simulations. The three methods entail setting the initial population size at a given value, and:

1) allow the populations to change through the simulation,
2) disable population modeling for the animal groups of interest,
3) enable culling of the populations of interest.

To use the first method in SavView, simply move to the parameter window, select "Animals" and the "Populations" window. Then select the animal groups of interest, and change the value.

Modified cattle population

Default cattle population



Increasing the initial population size of livestock is a helpful exercise if a one-time addition of livestock are anticipated. However, it may not be very realistic, in that livestock populations typically are supported from outside the system, and kept at whatever population level was considered appropriate.

When we review the results of a simulation of type '1', for example, we'll find that livestock populations declined rapidly, when their initial populations were set higher.

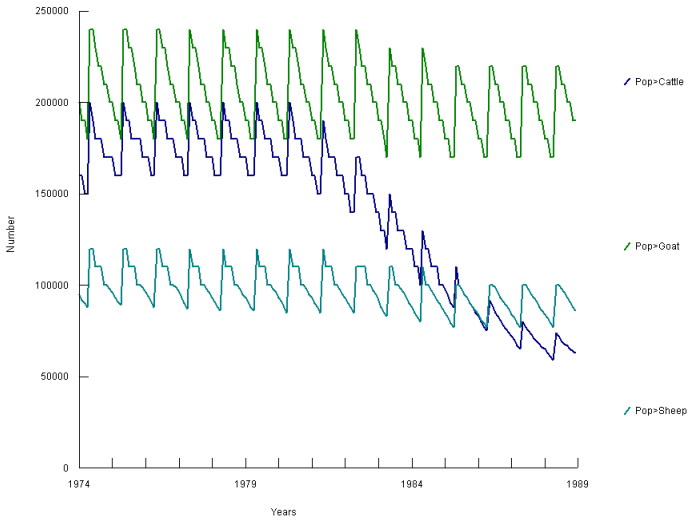
Exercise: As a group, we will review the effects of setting livestock populations at 150% of their current value (that is, setting cattle to 158,202, goats to 195,000, and sheep at 94,500).

Notes: Note that populations are set somewhat lower than recorded in the literature. This is because populations peak at higher numbers than the value set due to reproduction.

Experiments - More Livestock (continued)

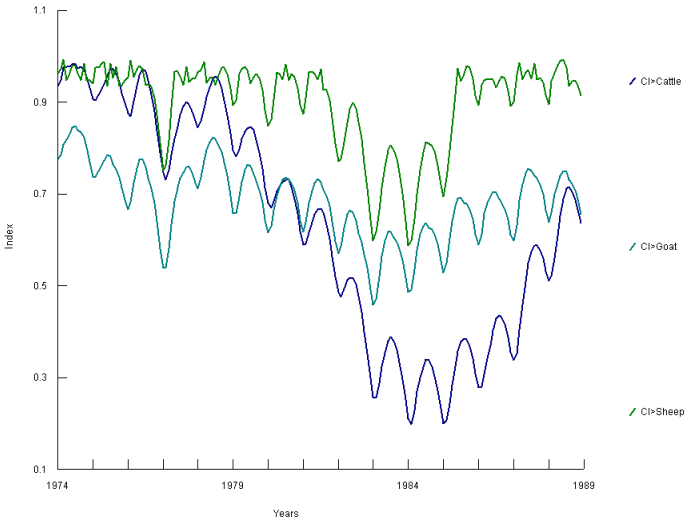
Livestock populations

Livestock populations appear to maintain themselves during the wetter early years, but cattle crash when a drier period occurs. This is due to their being crowded into the midlands of Ngorongoro because of the threat of MCF.

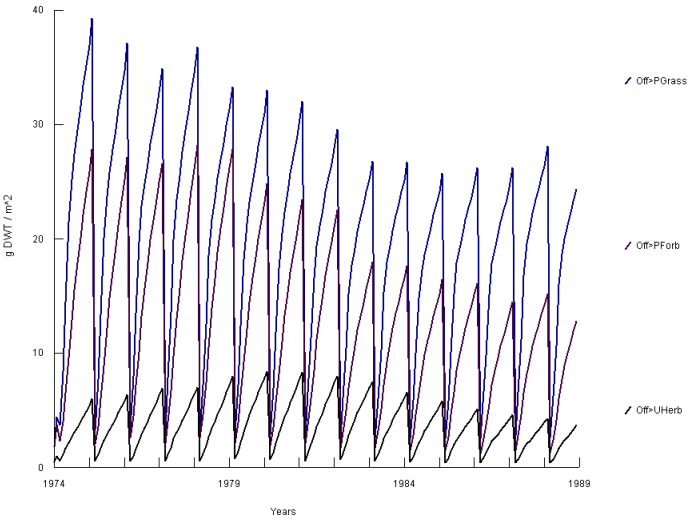


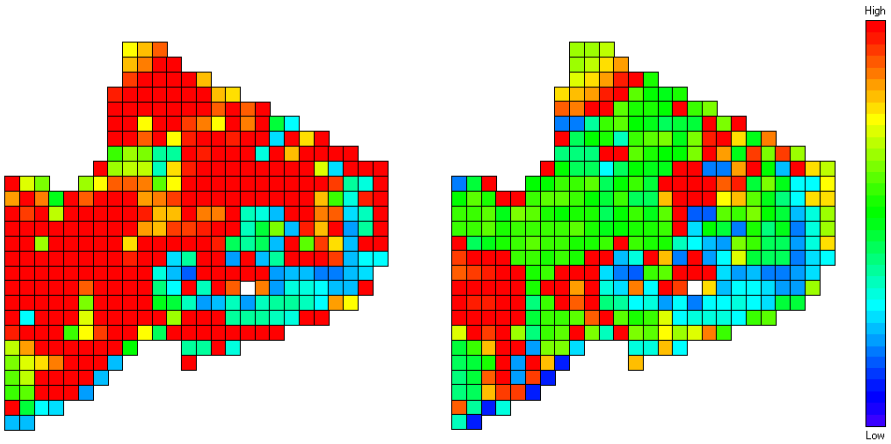
Livestock condition indices

Condition indices decline slightly to rapidly for livestock species, with the steepest decline during the drier years. As the cattle population collapses, the condition indices rebound in a density-depended response.



Offtake for herbaceous plants





Accumulated offtake for 1975 (left) and 1981 (right)

Offtake of herbaceous plants declines for the palatable groups, but increases for the unpalatable groups - a sign of overstocking on the system. Offtake declines rapidly after the collapse of cattle and declines in other livestock (and wildlife, not shown). Populations then begin to recover.

Experiments - More Livestock (continued)

Rather than setting an initial livestock population level, a helpful experiment would be to set the same population values, but disable population modeling for livestock. This will ensure that the livestock populations remain constant throughout the simulation. This might simulate immigration of livestock or animals contributed by donors, perhaps.

To use this second of our three methods, set the initial populations for livestock, as already described, and illustrated below. Then for each of the livestock groups (cattle, goats, and sheep), turn the population modeling off, as highlighted in the figure below with a circle.

The last method of modeling livestock is to enable culling. Animals may be culled at population numbers below the point where a crash may occur. Culling in Savanna can be implemented in several ways, but in general culling works as you would guess. When the population of an animal group reaches some maximum allowable limit (defined in SavView in the text boxes in the bottom of the

Modified cattle population

Default cattle population

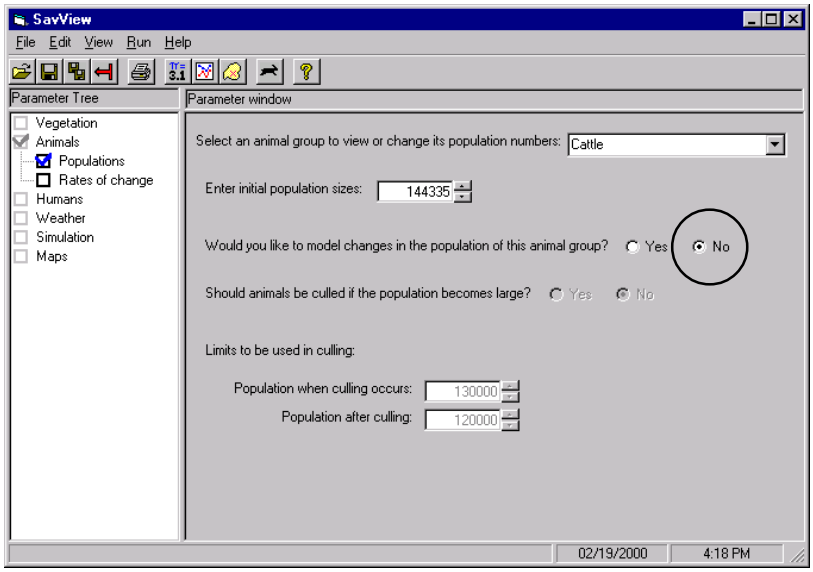


figure shown below), some number of animals are removed. The number of animals removed depends upon another value that may be set in SavView. The animals removed are summed and graphed, and for livestock, represent a benefit to households.

We will not be using culling in the exercise that follows; it will be used in later examples.

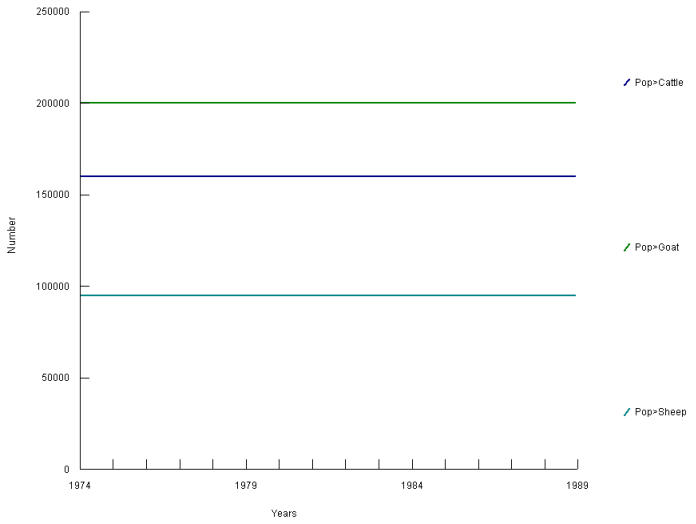
Exercise: Using SavView, set the livestock populations to 150% of their current value. That is, set cattle to 158,202, goats to 195,000, and sheep at 94,500. Disable population modeling for livestock, and run Savanna. After the model completes, compare the changes in plants and animals in response increased livestock populations.

Notes: This simulation may take as much as an hour to complete, depending upon the speed of the computer. A completed analysis is stored upon the accompanying CD disc. Note that populations are set somewhat lower than recorded in the literature. This is because populations peak at higher numbers than the value set due to reproduction.

Experiments - More Livestock (continued)

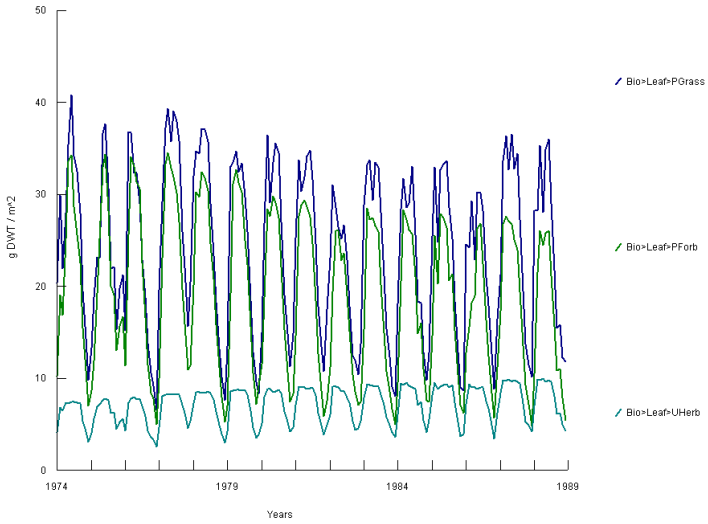
Livestock populations

Livestock populations are held constant in this experiment, representing external inputs into the system.

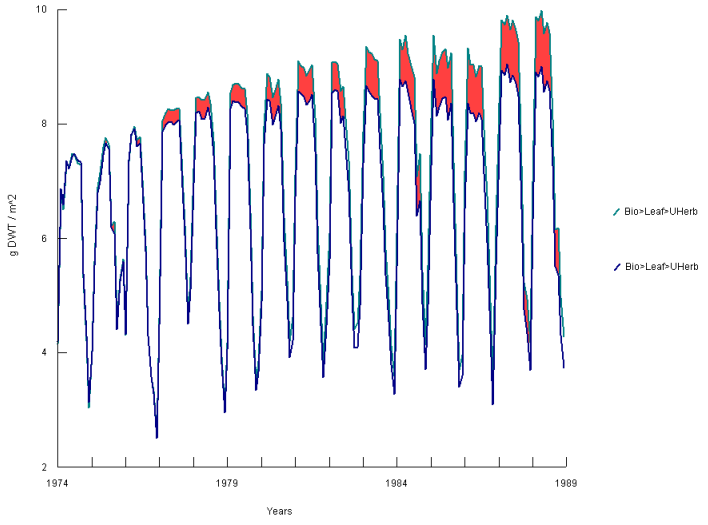


Leaf biomass for herbaceous plants

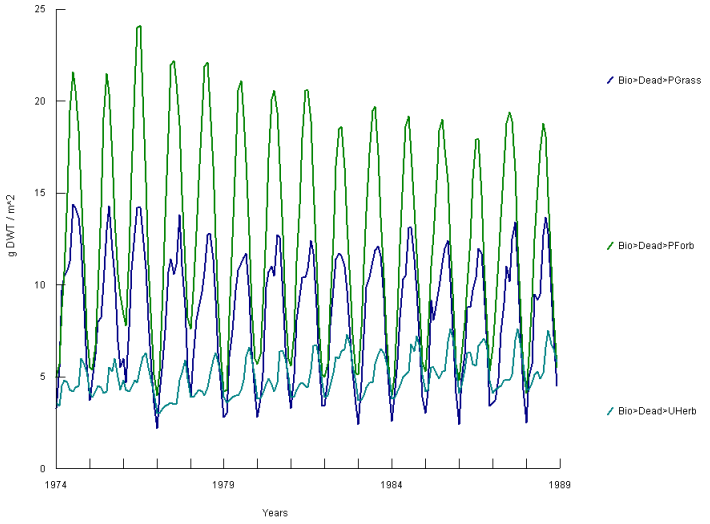
Herbaceous plants decline compared to the control model, except for unpalatable herbs, which increase somewhat. In general, additions of livestock favors unpalatable species and causes declines in palatable species.



A comparison of unpalatable herbs in the control model (the lower line) and with more livestock (the upper line)



The amount of dead plant material declines, both due to a reduction in the total plant biomass, and to increased use by animals under food-stress.

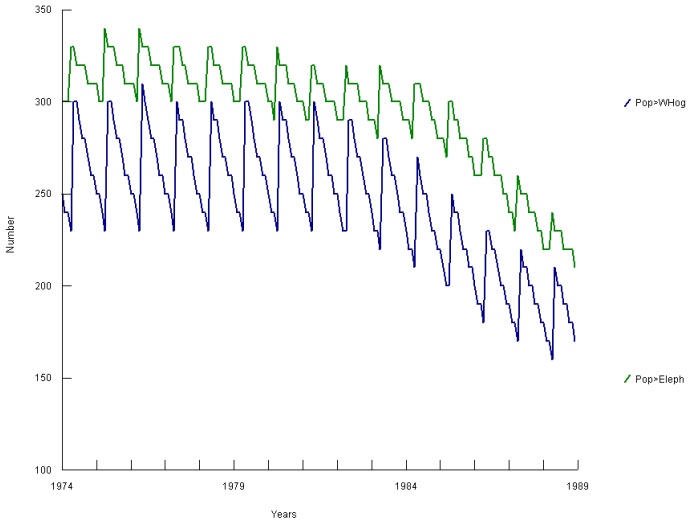


Note that comparisons between the experimental model, such as the addition of livestock, and the control model are straightforward if the machine being used can run two copies of SavView. Charts can be created in the two programs from the two model runs of interest, and the results compared.

Experiments - More Livestock (continued)

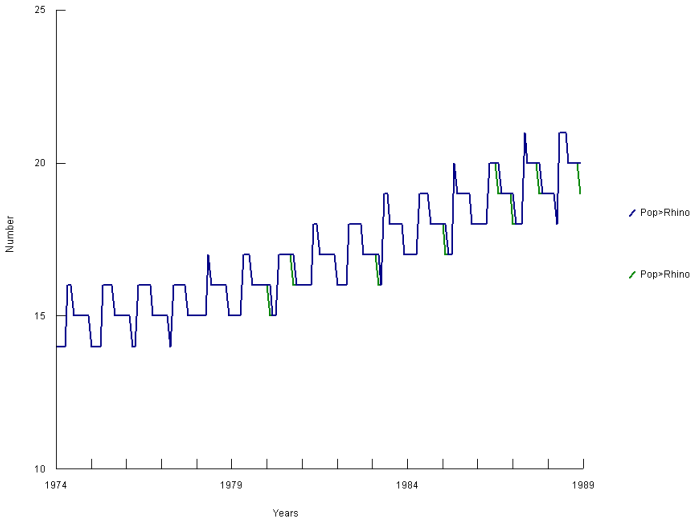
Warthog and elephant populations

When the numbers of livestock are increased, the fate of wildlife depends upon the group's spatial and dietary overlap with livestock. In the example shown, warthog and elephant eat a significant amount of herbs, and decline. An avoidance of cattle can lead to the decline as well.

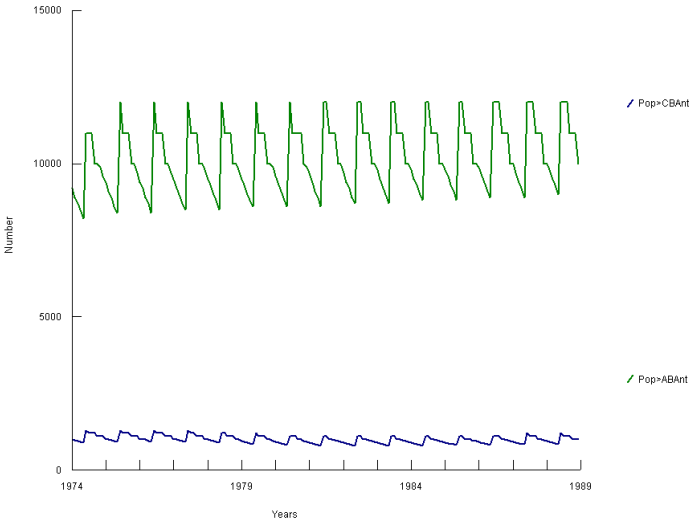


Rhinoceros population

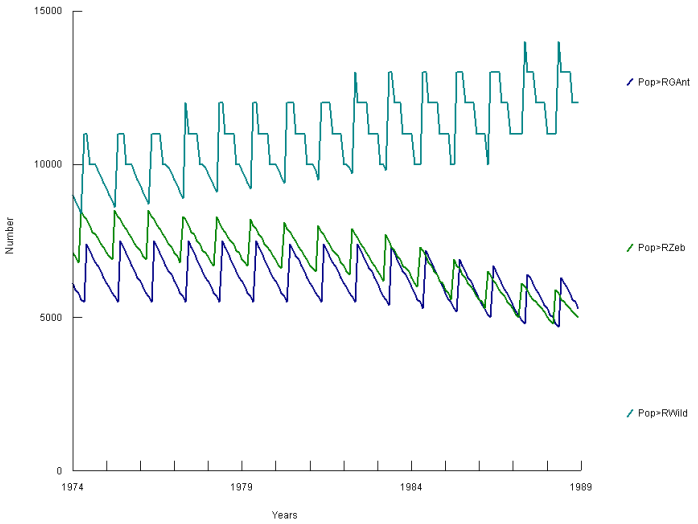
In contrast, rhino populations do not change at all - the rhinos occur in Ngorongoro Crater, where livestock are excluded.



Browsing antelope populations, within and outside Ngorongoro Crater



Other residential grazers, including residential wildebeest, zebra, and grazing antelope



Browsing antelope populations also remain quite stable, given that the antelope are feeding primarily on browse, overlapping only with goats in diet.

That same relationship is shown with the resident members of the migratory animals. Resident wildebeest are almost entirely within Ngorongoro Crater, and do not decline in response to more livestock. In contrast, resident zebra and grazing antelope decline.