

This is a discussion of a reimplementation of a model originally developed by M. Hegmon (Hegmon 1991). The model description follows the ODD protocol for describing individual- and agent-based models (Grimm et al. 2006) and consists of seven elements. The first three elements provide an overview, the fourth element explains general concepts underlying the model's design, and the remaining three elements provide details.

Overview

Purpose

The purpose of Hegmon's Sharing model is to develop an understanding of the effect sharing strategies have on household survival. The model was developed with western Pueblo agriculturalists, specifically the Hopi, in mind. Households are modeled as sharing no resources, pooling all of their resources into specified groups, or practicing restricted sharing. Resource pooling is the equal sharing of harvest yields by household in a group. Restricted sharing consists of households only sharing surplus harvest yields in equal amounts to the rest of an initially designated group. These three sharing types can be compared with respect to individual household survival over two twenty year periods. Households which fail to meet their caloric needs three times sequentially are eliminated from the simulation. The number of households in the simulation is determined by the user and can be varied however the user wishes. The size of groups for each sharing type as well as the number of groups can also be chosen by the user in order to better investigate the effects group size (i.e. household number) has upon group or household survival. For the purposes of comparison with Hegmon (1991), groups with between 2-10, 15 and 20 households are compared (see model comparison for more information).

State Variables and Scales

The most important state variable for this simulation is the household. It is distinguished by the type of sharing that the household will practice. Group size of sharing groups (i.e. the number of households) can be chosen by the modeler or is chosen at random, households which do not share have a group size of 1. Annual yield is calculated based on historical precipitation and growing season data as well as the field types for a given household. Field types are chosen at random for individual households.

Process Overview and Scheduling

The simulation is scheduled on a yearly basis. Each year, yields are calculated for each household. Weather data from 1932-1972 are used for the determination of yields (except the year 1955 which is skipped). However, the original model consists of two twenty year periods since the data comes from two different weather stations (1932-1951 & 1952-1972). The user may choose the start and end date when running the program. Also important to yield calculation is the type of fields. Depending on the type of sharing being practiced by a particular household, resources are distributed differently within each group. Households which do not practice sharing calculate yields and deposit extra into storage. Households which belong to a pooling group collect individual yields, then equally divide those resources among other households within their group. Households practicing restricted sharing first collect their harvest yields and only households with surplus distribute extra resources to households which have not met their caloric needs. This distribution takes place equally between households which have surplus. Thus, 1 kg of corn is taken from each household which has a surplus until all households in their group have met their own caloric needs, or they have no more corn surplus to share. Households which have

failed to meet their caloric needs (1017 kg) three times sequentially are then eliminated from the simulation. Any extra resources are added to harvest storage. Harvest storage is kept at the household level except for pooling groups which store harvest at a group level. All storage is kept for an indefinite amount of time.

Design Concepts

In this model, optimal group size and sharing type are determined for pueblo agriculturalist groups. Rainfall and growing season are kept constant for each year; however stochasticity is introduced throughout the yield calculation process. Part of this variation derives from 4 randomly chosen field suites which can be assigned to any household. The households themselves do not adapt to circumstances. Instead the model deduces the best adaptation through a comparison of the three sharing types and various group sizes. Since households do not utilize dynamic behavior, they do not perceive future or past events. Multiple groups can exist at the same time within the simulation. However, these groups do not interact with each other. Instead interaction occurs only with the sharing of corn resources within predetermined groups.

Fitness. Fitness can be understood by reference to survivability over two 20 year periods.

Prediction. Agents are not able to predict anything.

Sensing. Agents do not sense any part of the environment.

Interaction. Agents do not interact except within sharing groups by distributing resources to each other depending on the sharing type.

Stochasticity. Stochasticity exists in the assignment of field types, and calculation of farm yields.

Details

Initialization

Household initialization is largely determined by user control each run of the simulation. Sharing type is chosen by the user at the time of initialization. Group size as well as the number of groups which will be used on the model, are also chosen by the user at the initialization of the model. Historically recorded weather data for each year (except 1955) are available and used depending on the starting year chosen by the user. For the purposes of analysis (and because each period represents weather data from a different station), each simulation was run from 1931- 1951, or 1952-1972. The field types for a given household are chosen randomly from four compositions of three field types. Each household begins the simulation with 266 kg of corn in storage.

Input

The number of households per group as well as the sharing practiced by a group is chosen by the user. The main source of input for this model is precipitation data and growing season length data. This data comes from two weather stations near the Hopi mesas. All households require the same amount of annual calories from corn yields (1017kg) a number which derives from previous ethnological work. Two fields of akchin type (1.4 ha) are assigned to each household and a field of terrace (.32 ha), trinchera (.32 ha), or arroyo bottom (.32 ha), type may be assigned as a third field type. The fourth field set consists of two akchin fields (1.3 ha) and one dune seepage field (.63 ha).

Field Type	Corn Yield kg/ha
akchin	500
terrace	667
trinchera	667
arroyo bottom	667
dune seepage	425

Submodels

Yield Calculation

First each household submits the types of fields it has. Annual rainfall and growing season length are used to calculate yields. Each value is recorded as a percent of the mean rainfall for the area. Since rain can be localized in the area, stochastic variation is included for rainfall variation and growing season variation.

Growing Season Variation

Probability of Deviation	Change to Mean
2.5%	-15%
5%	-10%
85%	0
5%	10%
2.5%	15%

Precipitation Variation for all but terrace fields

Probability of Deviation	Change to Mean
5%	-30%
10%	-20%
70%	0
10%	20%
5%	30%

Precipitation Variation for terrace fields

Probability of Deviation	Change to Mean
5%	-20%
10%	-10%
70%	0
10%	10%
5%	20%

Variation in the form of storms, insects, or floods may also occur. Flooding does not occur for dune seepage fields.

Flooding

Fields	Probability of Occurrence		If flood occurs	
	if rainfall is x% of average	probability of flood	there is X% chance	that X% of yield survives
akchin, trinchera, or terrace	0-110	0		
	111-120	20	25	0
	121-130	50	50	50
	131+	100	25	75

	Probability of Occurrence		If flood occurs	
	if rainfall is x% of average	probability of flood	there is X% chance	that X% of yield survives
arroyo bottom	0-100	0	25	0
	101-120	20	50	50
	121+	50	25	75

For each field, each year, there is a 20% chance that grasshoppers will hit a field and a 10% chance that hailstorms will damage a field. For each of these events the table below shows the results.

X% chance	that X% of the yield survives
25	0
50	50
25	75

Affect of Weather conditions on Corn Yields is determined by the final amount of precipitation and growing season length for each field.

If Rainfall is X% of Average	Yield is X% of average
0-50	25
51-70	72
71-75	79
76-80	85
81-90	94
91-100	100
101-110	105
111+	111

If Growing Season is X% of Average	Yield is X% of average
50-75	67
76-80	81
81-90	97
91+	100

Pooling of Resources

Individual households are responsible for gathering their own yields with respect to the types of fields they were assigned. Once each household has collected its resources, it is then totaled with previous storage and divided among each of the households. If any surplus remains, the resources are kept in group storage for the following year

Restricted Sharing

Each household collects its yields based on the types of fields it has. The resources and any previous harvest are consumed and any surplus is then incrementally divided between households in its group which were not able to meet their caloric requirements (1017 kg). If resources remain, then those resources are redeposited into a household's storage.

No Sharing

Each household receives its annual corn yields, consumes 1017 kg and deposits any remaining resources into its own storage to be added to available resources the following year.

Mortality

If after harvests have been collected and sharing has occurred, a household has failed to fulfill its caloric requirements, it is believed to have starved. If a household starves three years consecutively, it is eliminated from the program.

Weather Data

-1932-1953 data are from Jeddito weather station, 1954-1972 are from Keams weather station.

Growing Season		July/Aug		Rainfall
Year	length	%mean	amount	%mean
1932	158	106	87	110
1933	153	103	52	66
1934	171	115	117	148
1935	164	110	129	163
1936	141	95	118	149
1937	168	113	75	95
1938	154	103	78	99
1939	133	89	23	29
1940	153	103	65	82
1941	106	71	83	105
1942	129	87	74	94
1943	150	101	108	137
1944	142	95	25	32
1945	156	105	78	99
1946	176	118	77	97

1947	193	130	86	109
1948	149	100	17	22
1949	155	104	123	156
1950	104	70	38	48
1951	142	95	59	75
1952	166	111	100	127
1953	127	85	111	141
1954	166	114	88	121
1956	151	104	87	119
1957	146	101	109	149
1958	171	118	36	49
1959	146	101	74	101
1960	144	99	22	30
1961	141	97	71	97
1962	155	107	11	15
1963	173	119	125	171
1964	162	112	70	96
1965	113	78	73	100
1966	172	119	69	95
1967	123	85	110	151
1968	113	78	50	68
1969	159	110	97	133
1970	131	90	52	71
1971	117	81	35	48
1972	153	106	102	140

References

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