Operations Research I, Term Group Project

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Implement components of a linear programming model for an independent family-owned farming operation. Formulate a model based on crop yields, livestock productivity, and labor wages which in turn renders decisions on how to maximize total net worth. Obtain optimal monetary returns and run weather sensitivity analysis on income.

I. Components of the Linear Programming Model (Part a)

The decisions to made are how much acreage should be planted in each of the crops and how many cows and hens to have for the coming year. The constraints on these decisions are amount of labor hours available, the investment funds available, the number of acres available, the space available in the barn and chicken coop, and the minimum requirements for feed to be planted. The overall measure of performance is monetary worth, which is to be maximized.

II. Model Formulation (for a "good" year, Part b)

1. Plantings

a) Decision Variables

SA : Number of acres planted for soy beans;

CA : Number of acres planted for corn;

WA : Number of acres planted for wheat;

WSHrsReq : Winter and spring labor hours required for plantings;

SFHrsReq : Summer and fall labor hours required for plantings;

NVP : Net value of crops;

AP : Acres planted;

TC : Total number of cows;

TH : Total number of hens;

b) Formulae/Constraints

[AcresPlanted]AP = SA + CA + WA;

[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;

[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;

[NetValPlanting]NVP = 70*SA + 60*CA + 40*WA;

[CornAcres]CA >= TC;

[WheatAcres]WA >= TH*0.05;

2. Livestock

a) Decision Variables

HRM : Hours required per month;

Cows : Number of cows in inventory;

Hens : Number of hens in inventory;

GL : Grazing land required;

NACI : Net annual cash income;

BLV : Beginning livestock value;

ECLV : Ending current livestock value;

ENLV : Ending new livestock value;

NC : Number of new cows;

NH : Number of new hens;

IF : Investment fund;

TC : Total number of cows;

TH : Total number of hens;

LIF : Left over investment fund;

LE : Living expenses;

b) Formulae/Constraints

LE = $40,000

Cows = 30

Hens = 2000

TC = Cows + NC

TH = Hens NH

IF = $20000

HRM = 10*TC + 0.05*TH

GL = 2*TC + 0*TH

NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;

ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;

TH <= 5000;

EVL = ECLV + ENLV;

LIF = IF - 1500*NC - 3*NH;

3. Neighboring Farm Work

a) Decision Variables

WSHrs : Hours worked in winter and spring;

SFHrs : Hours worked in summer and fall;

b) Wage Formula

Wages = 5*WSHrs + 5.50*SFHrs

4. Model Formulae (LINGO)

a) [TotalMonetaryWorth]max = (NVP + NACI + Wages) + (EVL + LIF) – LE;

b) [TotalAcreage]AP + GL <= 640;

c)[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;

d)[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;

See appendix for LINGO implementation and results.

III. Optimal Solution, Model Sensitivity, and Objective Function Value (Parts c and d)

The model predicts that the family's monetary worth at the end of the year will be **$99,367**.

LINGO Results

```
  Global optimal solution found.
  Objective value:                              99367.00
  Infeasibilities:                              0.000000
  Total solver iterations:                             1
  Elapsed runtime seconds:                          0.03

  Model Class:                                        LP

  Total variables:                    21
  Nonlinear variables:                 0
  Integer variables:                   0

  Total constraints:                  23
  Nonlinear constraints:               0

  Total nonzeros:                     64
  Nonlinear nonzeros:                  0
```

Variable	Value	Reduced Cost
AP	580.0000	0.000000
SA	450.0000	0.000000
CA	30.00000	0.000000
WA	100.0000	0.000000
WSHRSREQ	537.0000	0.000000
SFHRSREQ	736.0000	0.000000
NVP	37300.00	0.000000
TC	30.00000	0.000000
TH	2000.000	0.000000
LE	40000.00	0.000000
COWS	30.00000	0.000000

HENS	2000.000	0.000000
NC	0.000000	53.00000
NH	0.000000	0.8575000
IF	20000.00	0.000000
HRM	400.0000	0.000000
GL	60.00000	0.000000
NACI	34000.00	0.000000
BLV	40000.00	0.000000
ECLV	35250.00	0.000000
ENLV	0.000000	0.000000
EVL	35250.00	0.000000
LIF	20000.00	0.000000
WAGES	12817.00	0.000000
WSHRS	1063.000	0.000000
SFHRS	1364.000	0.000000
NI	84117.00	0.000000

Row	Slack or Surplus	Dual Price
ACRESPLANTED	0.000000	-57.30000
WSHRSPLANTING	0.000000	-5.000000
SFHRSPLANTING	0.000000	-5.500000
NETVALPLANTING	0.000000	1.000000
CORNACRES	0.000000	-8.400000
WHEATACRES	0.000000	-24.15000
TOTALMONETARYWORTH	**99367.00**	**1.000000**
TOTACREAGE	0.000000	57.30000
WSHOURS	0.000000	5.000000
SFHOURS	0.000000	5.500000
NETINC	0.000000	0.000000

Summary of LINGO Range Report

Decision Variables

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
SA	450	0	70	∞	8.4
CA	30	0	60	8.4	∞
WA	100	0	40	17.15	∞
NC	0	-53	700	53	∞
NH	0	-0.857	3.5	0.857	∞
WSHrs	1063	0	5	57.3	0.915
SFHrs	1364	0	5.5	34.5	0.930

Constraints

Name	Final Value	Shadow Price	Constraint RHS	Allowable Increase	Allowable Decrease
CA	30	-8.4	0	450	30
WA	100	-24.15	0	450	100
Cost of New Livestock Totals	$0	$0	20000	∞	20000
TC	30	0	42	∞	12
TH	2000	0	5000	∞	3000
W&S Hours Total	4000	5	4000	∞	1063
S&F Hours Total	4500	5.5	4500	∞	1364
Acreage Total	640	57.3	640	974.29	450

IV. Scenario Analysis (Part e)

(LINGO Models in Appendix)

Scenario	Soy Acres Planted	Corn Acres Planted	Wheat Acres Planted	New Cows	New Hens	W&S Hours Worked on Neighbors' Farms	S&F Hours Worked on Neighbors' Farms	Total Monetary Worth
Drought	0	42	133.33	12	667	562.2	1036.267	$67,864
Flood	0	422.667	133.33	12	667	219.6	579.4667	$74,055
Early Frost	450	30	100	0	0	1063	1364	$88,767
Drought & Early Frost	0	42	100	12	0	782.2	1259.6	$66,649
Flood & Early Fros	0	37.3333	250.0	7.333	3000	76.4	540.2	$69,860

V. Additional Scenario Analysis (Climate conditions change during the year, Part f)

	Family's monetary worth at year's end if the scenario is actually:					
Optimal Solution Used	Good Weather	Drought	Flood	Early Frost	Drought..EF	Flood..EF
Good Weather	$99,367	$57,117	$70,417	$88,767	$53,717	$67,367
Drought	$76,348	$67,864	$70,668	$74,174	$66,321	$69,581
Flood	$94,962	$57,929	$74,055	$85,175	$54,482	$69,162
Early Frost	$99,367	$57,117	$70,417	$88,767	$53,717	$67,367
Drought & Early Frost	$75,009	$67,859	$70,329	$73,169	$66,649	$69,409
Flood & Early Frost	$80,476	$67,676	$71,483	$77,230	$64,990	$69,860

The good weather solution is the riskiest. It has the widest swing from maximum to minimum monetary worth. The flood solution appears to be the mid-range of the variability in the swing from maximum to minimum monetary worth. The most conservative scenarios are drought, drought/early frost, and flood/early frost.

VI. Weighted Scenario Analysis (Parts g and h)

The expected net value for each of the crops is calculated as follows:

Soybeans: ($70)(0.4) + (-$10)(0.2) + ($15)(0.1) + ($50)(0.15) + (-$15)(0.1) + ($10)(0.05) = $34,

Corn: ($60)(0.4) + (-$15)(0.2) + ($20)(0.1) + ($40)(0.15) + (-$20)(0.1) + ($10)(0.05) = $27.5,

Wheat: ($40)(0.4) + ($0)(0.2) + ($10)(0.1) + ($30)(0.15) + (-$10)(0.1) + ($5)(0.05) = $20.75

See appendix for LINGO model.

The model predicts that the family's monetary worth at the end of the year will be **$80,537**.

LINGO Results

```
  Global optimal solution found.
  Objective value:                              80537.00
  Infeasibilities:                              0.000000
  Total solver iterations:                             1
  Elapsed runtime seconds:                          0.05

  Model Class:                                        LP

  Total variables:                    20
  Nonlinear variables:                 0
  Integer variables:                   0
```

Total constraints:	22
Nonlinear constraints:	0
Total nonzeros:	60
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
AP	556.0000	0.000000
SA	414.0000	0.000000
CA	42.00000	0.000000
WA	100.0000	0.000000
WSHRSREQ	511.8000	0.000000
SFHRSREQ	700.0000	0.000000
NVP	17306.00	0.000000
TC	42.00000	0.000000
TH	2000.000	0.000000
LE	40000.00	0.000000
COWS	30.00000	0.000000
HENS	2000.000	0.000000
NC	12.00000	0.000000
NH	0.000000	0.000000
IF	20000.00	0.000000
HRM	520.0000	0.000000
GL	84.00000	0.000000
NACI	44200.00	0.000000
BLV	40000.00	0.000000
ECLV	35250.00	0.000000
ENLV	16200.00	0.000000
EVL	51450.00	0.000000
LIF	2000.000	0.000000
WAGES	5581.000	0.000000
WSHRS	368.2000	0.000000
SFHRS	680.0000	0.000000

Row	Slack or Surplus	Dual Price
ACRESPLANTED	0.000000	-21.30000
WSHRSPLANTING	0.000000	-5.000000
SFHRSPLANTING	0.000000	-5.500000
NETVALPLANTING	0.000000	1.000000
CORNACRES	0.000000	-4.900000
WHEATACRES	0.000000	-7.400000
TOTALMONETARYWORTH	**80537.00**	**1.000000**
TOTACREAGE	0.000000	21.30000
WSHOURS	0.000000	5.000000
SFHOURS	0.000000	5.500000

Summary of LINGO Range Report

Decision Variables

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
SA	414	0	34	7.5	0.4
CA	42	0	27.5	4.9	22.5
WA	100	0	20.75	0.4	∞
NC	12	0	700	∞	22.5
NH	0	0	3.5	0.02	∞
WSHrs	368.2	0	5	0.389	0.071
SFHrs	680	0	5.5	0.395	0.075

Constraints

Name	Final Value	Shadow Price	Constraint RHS	Allowable Increase	Allowable Decrease
CA	42	-4.9	0	414	42
WA	100	-7.40	0	414	100
Cost of New Livestock Totals	$18000	$0	20000	∞	2000
TC	42	22.5	42	1.333	12
TH	2000	0	5000	∞	3000
W&S Hours Total	4000	5	4000	∞	368.2
S&F Hours Total	4500	5.5	4500	∞	680
Acreage Total	640	21.3	640	368.2	414

VII. Loan Analysis (Part i)

The shadow price for the investment constraint is $0. This is interpreted as meaning the additional investment funds will not increase the total monetary worth. Thus, a loan application will be denied – it's not worth taking out a loan. The shadow price must reach $1.10 before a loan at 10% interest would be payable.

VIII. Crop Postoptimality Analysis (Part j)

1. The expected net value for soybeans can increase up to $7.50 or decrease up to $0.40.

2. The expected net value for corn can increase up to $4.90 or decrease up to $22.50.

3. The expected net value for wheat can increase up to $0.40 or decrease any amount without changing the optimal solution.

The solution is sensitive to decreases in the expected value of soybeans and increases in the expected value of wheat. If the *cumulative* decrease in the expected value of soybeans *and* increase in the expected value of wheat exceeds $0.40, then the 100% rule will be violated, and the solution may change.

Total Monetary Worth	Wheat Expected Net Value					
Soybeans Expected Net Value	$80,537	$18.75	$19.75	$20.75	$21.75	$22.75
	$32	$79,509	$76,629	$79,788	$79,976	$80,217
	$33	$79,923	$80,023	$80,143	$80,308	$80,505
	$34	$80,337	$80,437	$80,537	$80,657	$80,829
	$35	$80,751	$80,851	$80,951	$81,051	$81,171
	$36	$81,165	$81,265	$81,365	$81,465	$81,565

IX. Another Example(Part k)

A comparable example would involve the manufacturing of cell phone. Rare-earth elements comprise the make-up of cell phone circuit boards and those substances are mined in China and South America. Thus, the acquisition and costs of those resources are sensitive to mining policies and political uncertainties. Furthermore, cell phones are manufactured in foreign sites and labor wages may prove to be volatile. Finally, fluctuating costs of engineering design and shipping prove significant in a highly competitive market.

X. Appendix: LINGO Model Source (may be downloaded from http://rfrith.uaa.alaska.edu)

1. Good weather model

```
!Plantings;
!SA                : soy acres;
!CA                : corn acres;
!WA                : wheat acres;
!WSHrsReq          : W&S hours required;
!SFHrsReq          : S&F hours required;
!NV                : Net value;
!AP                : Acres planted;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 70*SA + 60*CA + 40*WA;
[CornAcres]CA >= TC;
[WheatAcres]WA >= TH*0.05;
```

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM               : Hours required per month;
!Cows              : # of cows;
!Hens              : # of hens;
!GL                : Grazing Land Required;
!NACI              : Net annual cash income;
!BLV               : Beginning livestock value;
!ECLV              : Ending current livestock value;
!ENLV              : Ending new livestock value;
!EVL               : Ending value of livestock;
!NC                : New Cow;
!NH                : New Hen;
!IF                : Investment fund;
!TC                : Total cows;
!TH                : Total hens;
!LIF               : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
Cows = 30;
Hens = 2000;
!NC = 0;
!NH = 0;
TC = Cows + NC;
TH = Hens + NH;

IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs             : Hours worked in winter and spring;
!SFHrs             : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;


[TotalMonetaryWorth]max = (NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
```

2. Drought model

```
!Plantings;
!SA                : soy acres;
!CA                : corn acres;
!WA                : wheat acres;
!WSHrsReq          : W&S hours required;
!SFHrsReq          : S&F hours required;
!NV                : Net value;
!AP                : Acres planted;
!TC                : Total cows
!TH                : Total hens
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 10*SA + 15*CA + 0*WA;
[CornAcres]CA >= TC;
[WheatAcres]WA >= TH*0.05;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM               : Hours required per month;
!Cows              : # of cows;
!Hens              : # of hens;
!GL                : Grazing Land Required;
!NACI              : Net annual cash income;
!BLV               : Beginning livestock value;
!ECLV              : Ending current livestock value;
!ENLV              : Ending new livestock value;
!EVL               : Ending value of livestock;
!NC                : New Cow;
!NH                : New Hen;
!IF                : Investment fund;
!TC                : Total cows;
!TH                : Total hens;
!LIF               : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
Cows = 30;
Hens = 2000;
TC = Cows + NC;
TH = Hens + NH;

IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;
```

```
TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs            : Hours worked in winter and spring;
!SFHrs            : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;

[TotalMonetaryWorth]max = (-1*NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
```

3. Drought..Early Frost model

```
!Plantings;
!SA               : soy acres;
!CA               : corn acres;
!WA               : wheat acres;
!WSHrsReq         : W&S hours required;
!SFHrsReq         : S&F hours required;
!NV               : Net value;
!AP               : Acres planted;
!TC               : Total cows
!TH               : Total hens
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 15*SA + 20*CA + 10*WA;
[CornAcres]CA >= TC;
[WheatAcres]WA >= TH*0.05;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM              : Hours required per month;
!Cows             : # of cows;
!Hens             : # of hens;
!GL               : Grazing Land Required;
!NACI             : Net annual cash income;
!BLV              : Beginning livestock value;
!ECLV             : Ending current livestock value;
!ENLV             : Ending new livestock value;
!EVL              : Ending value of livestock;
!NC               : New Cow;
!NH               : New Hen;
!IF               : Investment fund;
!TC               : Total cows;
!TH               : Total hens;
!LIF              : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
```

```
Cows = 30;
Hens = 2000;
!NC = 0;
!NH = 0;
TC = Cows + NC;
TH = Hens + NH;

IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs            : Hours worked in winter and spring;
!SFHrs            : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;

[TotalMonetaryWorth]max = (-1*NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
```

4. Early Frost model

```
!Plantings;
!SA               : soy acres;
!CA               : corn acres;
!WA               : wheat acres;
!WSHrsReq         : W&S hours required;
!SFHrsReq         : S&F hours required;
!NV               : Net value;
!AP               : Acres planted;
!TC               : Total cows
!TH               : Total hens
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 50*SA + 40*CA + 30*WA;
[CornAcres]CA >= TC;
```

```
[WheatAcres]WA >= TH*0.05;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM               : Hours required per month;
!Cows              : # of cows;
!Hens              : # of hens;
!GL                : Grazing Land Required;
!NACI              : Net annual cash income;
!BLV               : Beginning livestock value;
!ECLV              : Ending current livestock value;
!ENLV              : Ending new livestock value;
!EVL               : Ending value of livestock;
!NC                : New Cow;
!NH                : New Hen;
!IF                : Investment fund;
!TC                : Total cows;
!TH                : Total hens;
!LIF               : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
Cows = 30;
Hens = 2000;
!NC = 0;
!NH = 0;
TC = Cows + NC;
TH = Hens + NH;

IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!HRM = 10*Cows + 0.05*Hens;
!GL = 2*Cows + 0*Hens;
!BLV = 35000 + 5000;
!ELV = 0.9*35000 + 0.75*Hens;
!Cows + NC <= 42;
!Hens + NH <= 5000;
!1500*NC + 3*NH <= IF;
!NACI = 850*(Cows) + 4.25*(Hens);
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs             : Hours worked in winter and spring;
```

```
!SFHrs              : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;


[TotalMonetaryWorth]max = (NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
!;
[NetInc]NI = NVP + NACI + Wages;
```

5. Flood model

```
!Plantings;
!SA                 : soy acres;
!CA                 : corn acres;
!WA                 : wheat acres;
!WSHrsReq           : W&S hours required;
!SFHrsReq           : S&F hours required;
!NV                 : Net value;
!AP                 : Acres planted;
!TC                 : Total cows
!TH                 : Total hens
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 15*SA + 20*CA + 10*WA;
[CornAcres]CA >= TC;
[WheatAcres]WA >= TH*0.05;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM                : Hours required per month;
!Cows               : # of cows;
!Hens               : # of hens;
!GL                 : Grazing Land Required;
!NACI               : Net annual cash income;
!BLV                : Beginning livestock value;
!ECLV               : Ending current livestock value;
!ENLV               : Ending new livestock value;
!EVL                : Ending value of livestock;
!NC                 : New Cow;
!NH                 : New Hen;
!IF                 : Investment fund;
!TC                 : Total cows;
!TH                 : Total hens;
!LIF                : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
Cows = 30;
Hens = 2000;
!NC = 0;
!NH = 0;
TC = Cows + NC;
TH = Hens + NH;
```

```
IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!HRM = 10*Cows + 0.05*Hens;
!GL = 2*Cows + 0*Hens;
!BLV = 35000 + 5000;
!ELV = 0.9*35000 + 0.75*Hens;
!Cows + NC <= 42;
!Hens + NH <= 5000;
!1500*NC + 3*NH <= IF;
!NACI = 850*(Cows) + 4.25*(Hens);
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs            : Hours worked in winter and spring;
!SFHrs            : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;


[TotalMonetaryWorth]max = (NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
!;
[NetInc]NI = NVP + NACI + Wages;
```

6. Flood..Early Frost model

```
!Plantings;
!SA               : soy acres;
!CA               : corn acres;
!WA               : wheat acres;
!WSHrsReq         : W&S hours required;
!SFHrsReq         : S&F hours required;
!NV               : Net value;
!AP               : Acres planted;
!TC               : Total cows
!TH               : Total hens
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
```

```
[AcresPlanted]AP = SA + CA + WA;
[WSHrsPlanting]WSHrsReq = 1*SA + 0.9*CA + 0.6*WA;
[SFHrsPlanting]SFHrsReq = 1.4*SA + 1.2*CA + 0.7*WA;
[NetValPlanting]NVP = 10*SA + 10*CA + 5*WA;
[CornAcres]CA >= TC;
[WheatAcres]WA >= TH*0.05;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Livestock;
!HRM              : Hours required per month;
!Cows             : # of cows;
!Hens             : # of hens;
!GL               : Grazing Land Required;
!NACI             : Net annual cash income;
!BLV              : Beginning livestock value;
!ECLV             : Ending current livestock value;
!ENLV             : Ending new livestock value;
!EVL              : Ending value of livestock;
!NC               : New Cow;
!NH               : New Hen;
!IF               : Investment fund;
!TC               : Total cows;
!TH               : Total hens;
!LIF              : Leftover investment fund;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
LE = 40000;
Cows = 30;
Hens = 2000;
!NC = 0;
!NH = 0;
TC = Cows + NC;
TH = Hens + NH;

IF = 20000;

HRM = 10*TC + 0.05*TH;
GL = 2*TC + 0*TH;
NACI = 850*(TC) + 4.25*(TH);

BLV = 35000 + 5000;
ECLV = 0.9*35000 + 0.75*5000;

1500*NC + 3*NH <= 20000;

ENLV = (0.9*1500)*NC + (0.75*3)*NH;

TC <= 42;
TH <= 5000;

EVL = ECLV + ENLV;
LIF = IF - 1500*NC - 3*NH;

!HRM = 10*Cows + 0.05*Hens;
!GL = 2*Cows + 0*Hens;
!BLV = 35000 + 5000;
!ELV = 0.9*35000 + 0.75*Hens;
!Cows + NC <= 42;
!Hens + NH <= 5000;
```

```
!1500*NC + 3*NH <= IF;
!NACI = 850*(Cows) + 4.25*(Hens);
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
!Neighboring Farm Work;
!WSHrs            : Hours worked in winter and spring;
!SFHrs            : Hours worked in summer and fall;
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!;
Wages = 5*WSHrs + 5.50*SFHrs;


[TotalMonetaryWorth]max = (NVP + NACI + Wages) + (EVL + LIF) - LE;
[TotAcreage]AP + GL <= 640;
[WSHours]WSHrsReq + 6*HRM + WSHrs <= 4000;
[SFHours]SFHrsReq + 6*HRM + SFHrs <= 4500;
!;
[NetInc]NI = NVP + NACI + Wages;
```