Agland Decision Tool: A Multicriteria Decision Support System for Agricultural Property

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Abstract: From sustainability to productivity, agricultural land use issues involve complex multiobjective decision making problems. The *Agland Decision Tool* is an Excel based decision support system designed to help agricultural property managers make informed production decisions. Using the *Agland Decision Tool*, managers can build and compare up to five different production alternatives on the basis of: landlord returns, tenant returns, weather reduction risks, flexibility, capital outlay, labor requirements, and erosion control and sustainability. The alternatives are ranked using the multi-criteria decision making methods: PROMETHEE and weighted average. The ability to compare results using two different ranking methods provides the decision maker valuable insight into the decision making process. The program was designed and this paper was written using the author's own agricultural property as a baseline example. The property is a multi-use dryland cropping system located in the high plains of western Nebraska in the United States. Three cash crops and three pasture grazing alternatives are used to build five production alternatives for comparison. The ranking results identify two clear choices, with PROMETHEE and weighted average each producing a different top alternative. Analysis of the ranking process clearly identifies the important factors influencing the different final rankings under each method. Thus, the essential elements to be traded off in narrowing the selection to one choice are clearly identified for the decision maker. This paper provides valuable insight into the decision making process of an actual agricultural landowner. The development of decision support tools, like *Agland Decision Tool*, are an important element in aiding agricultural land managers in maintaining the long-term sustainability of agricultural production systems.

Keywords: Multiobjective decision making; Land use; Agricultural production decisions.

1. INTRODUCTION

Agricultural land use decisions are generally complex, involving both qualitative as well as quantitative factors. Developing a production plan from among the numerous alternatives is not an easy task. While many land use decision makers rely entirely on heuristics and "gut instinct", the utilization of a multicriteria decision support system (MCDSS) can be a tremendous aid in the decision making process. Production plans identified as preferred through a MCDSS could then be further analyzed in depth before final implementation.

Several multicriteria decision making (MCDM) methods have been developed that might be useful for analyzing agricultural land use. These include the weighted average method, PROMETHEE, ELECTRE, compromise programming, goal programming, and the analytical hierarchy process (AHP) [Raju and Pillai, 1999]. The present paper deals with a decision support system analyzing five production alternatives with respect to seven discrete criteria, namely, landlord returns, tenant returns, weather reduction risks, flexibility, capital outlay, labor requirements, and erosion control and sustainability. Three different MCDM methods are employed to analyze the decision: the weighted average method, PROMETHEE I, and PROMETHEE II.

PROMETHEE is an outranking method where the intensity of the preference for alternative a over alternative b with regards to each criteria j is measured in terms of a preference function $P_j(a,b)$. Brans et. al. [1986] proposed six types of preference functions, which we categorize as the insensitive criterion, the indifference criterion, the linear criterion, the level criterion, the linear criterion with indifference, and the Gaussian criterion. A weighted average of the preference functions is calculated to obtain a rank ordering of the alternatives. PROMETHEE I provides a partial preordering of the alternatives through a pairwise dominance comparison of positive and negative outranking flows. PROMETHEE II provides a complete preordering through a comparison of net outranking flows.

The subject of the present paper, *Agland Decision Tool*, is an Excel-based decision support system incorporating PROMETHEE I, PROMETHEE II, and the weighted average methods into a multicriteria decision making process for agricultural land management. The weighted averaged method provides an uncomplicated ranking in comparison to the more powerful PROMETHEE methods. The baseline ranking provided by the weighted average method aids in the identification of the essential criteria to be traded off in narrowing the selection to one preferred alternative.

2. PROBLEM DESCRIPTION

2. 1 Introduction

Motivation for the development of the *Agland Decision Tool* was the purchase of 129.5 hectares of agricultural property by the author (figure 1). The property is located in the panhandle of Nebraska. The author co-owns the adjoining property to the east providing a water source that increases the production value of the grass pasture on the purchased property.

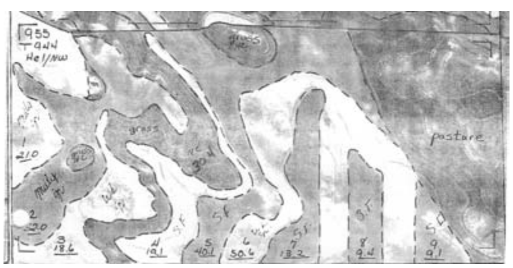

Figure 1. Field map of the agricultural property.

When the author first began consideration of the land purchase, it became apparent that there were a number of options available for using the land in agricultural production. Through consultation with the current tenant, several options were identified and back of the envelope calculations were made to provide an estimate of the worthiness of purchasing the property. As a part of this exercise, the value of a decision tool that calculated and compared various production plans on a multicriteria basis became apparent. Thus, the *Agland Decision Tool* was born.

2.2 Decision Description

Decisions need to be made about what to produce on 129.5 hectares of agricultural land. The property currently contains approximately 28.3 hectares of fenced grassland on the east, which the tenant cash rents at $12.35 per hectare. Of the remaining land, 14.9 hectares are unfenced grass and 86.3 hectares are cropland.

The cropland has produced a variety of dryland crops over the years including hard red winter wheat, proso millet, and oil sunflowers. Approximately 44.8 hectares of productive "bottom ground" is contained in fields 5, 6, 7, and 8 of figure 1. Both the tenant and the landlord agree that consideration should be given to taking some of the less productive ground in fields 1, 2, 3, 4, and 9 out of crop production and converting it to livestock grazing. However, most of this less productive cropland lies on the top of a plateau on the western side of the property, away from the water source to the east. Therefore, consideration needs to be given to the capital expense required to provide a water source for any livestock grazing on the western side of the property.

The landlord and tenant would like to consider two different options for new pasture. The first option is a permanent change. That would involve constructing a permanent fence line around any new pasture on the west and connecting it via fencing along the northern edge of the property to the existing pasture on the east. This would involve approximately 4 km of new fence but would also encompass the 14.9 hectares of currently unfenced grass and put it into production. Grass would need to be established on any converted cropland. The option would have considerable capital expense up front but, once established, the ongoing operating expenses would be minimal.

The second option is to add temporary pasture. This would involve planting annual grazing crops and constructing temporary fence lines. There would be a small capital investment in the original fencing materials and yearly cash expenditures for crop establishment as well as maintenance of fencing equipment. Labor would

Base Information

Total Hectares:	129.5

Decision Criteria			
Criteria	Weights	Preference Functions	Parameter
Landlord Returns	7	Type 3: Linear	1000
Tenant Returns	2	Type 3: Linear	1000
Weather Reduction	6	Type 6: Gaussian	425
Flexibility	5	Type 1: Insensitive	
Capital Outlay	4	Type 3: Linear	1000
Labor Requirements	1	Type 6: Gaussian	170
Erosion Control & Sustainability	3	Type 1: Insensitive	
*Enter weights for each factor. The higher the weight, the more that criteria will be considered in the decision making.			

Return to the Main Menu
Alternatives
Crop Info
Pasture Info

Figure 2. Base information interface. The user can adjust the weights and parameters.

Crop Database

Crop	Operating Expenses	Shared Input Expenses	Shared Revenue	Weather Reduction Factor	Land Units	Labor Require-ments
Wheat/Fallow	42	15.5	178	0.08	2	4.1
Sunflowers	37	37	220	0.08	1	4.2
Millet	39	20	185	0.20	1	3.3
Fallow	17	7	0	0.00	1	0.0

Return to the Main Menu
Alternatives
Pasture Info

Figure 3. The database interface for crops.

obviously be higher than with a permanent pasture. However, this option provides tremendous flexibility. If the conditions warrant a change from such a system, it can be done quickly with little loss of investment.

In addition to evaluating the possibilities of expanding the pasture, we wish to evaluate the various cropping options. All of this needs to be done on a comparative basis with an eye toward maximizing profits from operations in addition to minimizing exposure to weather related risks, maximizing flexibility, minimizing labor requirements, and maximizing erosion control and sustainability. Consideration also needs to be given to capital investment expenditures with a desire for less rather than more. This naturally leads to a need for a multicriteria decision support tool.

3. AGLAND DECISION TOOL

The *Agland Decision Tool* program is a series of Microsoft Excel worksheets linked by action buttons. After an initial introduction page, the user is presented with a main menu and the following options: enter base information; alternatives; crop info; pasture info; view payoff matrix; view PROMETHEE; view weighted average; or view results.

First, the user will establish the base information (see figure 2) including the number of hectares involved and the weighting factors for the seven criteria.

For our evaluation, criteria directly affecting the landlord were given the highest weight. However, this may not always be the case and these weights can be adjusted to meet the desires of any specific user.

For the PROMETHEE method, the preference relation functions are established by the program. A linear relation function is used for the landlord and tenant returns as well as the capital outlay. A Gaussian relation function is used for the weather reduction and labor requirements criteria. This is done because of what we view as a little more uncertainty regarding estimates of these two criteria. The intent is to create a little bit of an "indifference" buffer without resorting to a two parameter preference relation like the linear relation function with indifference. The other two criteria, flexibility and erosion control and sustainability, are ranked using a crisp or insensitive relation function. Values for these two criteria are limited to a five point scale from poor to excellent and a crisp relation function seems most appropriate.

Although these relation functions are establish a priori, the user can still influence how alternatives are compared on a criteria by criteria

Pasture Database

Pasture	Hectares per Head	Land Operating Expenses	Shared Input Expenses	Cash Rent	Land Units	Labor Require-ments	Capital Outlay
Permanent +	4	0	0	12.35	1	0	17000
Current Grass	4	0	0	12.35	1	0	0
Temporary +	3	14.5	26.4	19.76	1	2.2	500

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Alternatives

Crop Info

Livestock Information
(per head)

Operating Expenses	Revenue	Labor
161	426	7.7

Figure 4. The database interface for pasture and livestock.

Alternative 4:

Crop Information:

Hectares:	44.8

Crops	Operating Expenses	Shared Input Expenses	Shared Revenue	Weather Reduction Factor	Land Units	Labor Require-ments
Wheat/Fallow	42	15.5	178	0.08	2	4.1

Pasture Information:

Hectares:	84.7

Pasture	Hectares	Operating Expenses	Shared Input Expenses	Cash Rent	Land Units	Labor Require-ments	Capital Outlay
Current Grass	43.3	40.3	0	12.35	1	1.9	0
Permanent +	41.4	40.3	0	12.35	1	1.9	17000

Wasteland:	0

Flexibility: Poor   Erosion Control & Sustainability: Excellent

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Alternatives

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Next

Figure 5. The interface for entering each alternative. In this case, Alternative 4 combines a wheat/fallow crop rotation with the establishment of new permanent pasture.

basis. This is done by defining parameters for the linear and Gaussian preference relations. All of this is done in the base information screen and can be altered by the user at any time to test the sensitivity of the results.

After establishing the base information, the user will need to enter crop and pasture data. This can be done by clicking the crop info and the pasture info action buttons, respectively. Four crops are established in our crop database (see figure 3): wheat/fallow, sunflowers, millet, and fallow. This really constitutes three crops with a fallow only program in case wheat/fallow is not included in the rotation. The user provides data for each of the crops regarding operating expenses, shared input expenses and revenues, a weather reduction factor, land units, and labor requirements. Operator input and production history is crucial in establishing these input values. The program is designed to automatically assume that shared revenues and expenses are split at one-third for the landlord and two-thirds for the tenant, the common practice in the U.S. The weather reduction factor gives the user an opportunity to adjust revenues for weather losses. Rather than establish revenues as an historical average, the program is designed for revenues to represent expected values of yield times price. Then, the weather reduction factor captures the downward risk represented by severe weather events. Land units for most crops will always be one. However, in the case of wheat/fallow, for every hectare of growing wheat there will be one hectare of ground lying fallow. Therefore, land units for wheat/fallow is two.

Our pasture database contains three pasture options (see figure 4): current grass, permanent +, and temporary +. Permanent + and temporary + represent the options of adding to the current grass base. Of course, the current grass carries with it no significant expenses and it rents for $12.35 per hectare. Any operating and labor expenses associated with grazing livestock on the current grass are established as a part of the livestock information. The permanent pasture addition carries with it a significant capital outlay to cover the initial establishment. Meanwhile, the temporary pasture carries significant operating and share expenditures to cover annual crop establishment. The livestock information is automatically carried through the pasture calculations based on hectares per head. For example, if the livestock operating expenses are $161 per unit and 4 hectares of pasture is required for each unit, then the operating expenses related to the livestock is $40.25 per hectare.

With crop and pasture data established, we build the alternative production plans. As mentioned above, *Agland Decision Tool* allows the user to compare up to five alternatives. By clicking an "Alternatives" action button, the user can enter the alternatives menu where action buttons for each of the five alternatives are established. For each alternative, the user will have an opportunity to designate the number of crop hectares to be grown and establish a crop rotation by selecting from among the crops in the crops database (see figure 5). Then, the user can identify a production plan for pasture by selecting from the pasture database and establishing the number of hectares. At the bottom of each alternative screen are the entry prompts for the two subjective criteria: flexibility and erosion control and flexibility.

With the alternative production plans established, PROMETHEE I, PROMETHEE II, and weighted average calculations are carried out automatically by the program. The results tab gives a ranking of the alternatives from each of these methods (see figure 6). Of, course PROMETHEE I simply lists any dominance relations that have been identified. If desired, the user can also view the payoff matrix that was used to produce these results as well as the actual PROMETHEE and weighted average calculations.

4. RESULTS

For our scenario outlined above, five different production alternatives were established. For the first alternative, the production plan involved a traditional wheat/fallow rotation on all of the cropland while leaving the pasture situation as is with use of only the current 28.3 hectares of fenced grass. This plan has good flexibility but only fair erosion control and sustainability.

Alternatives 2 and 3 involve a little more elaborate crop rotation with the pasture situation unchanged from the current 28.3 hectares of fenced grass. Alternative 2 uses a crop rotation of wheat/fallow and millet. Its erosion control jumps up to good as a result of the increased crop cover and flexibility is very good. Alternative 3 uses a crop rotation of wheat/fallow, millet, and sunflowers. Its erosion control is very good and flexibility is very good.

RESULTS			
	PROMETHEE I Dominates	PROMETHEE II Ranking	Weighted Average Ranking
Alternative 1		4	4
Alternative 2	1, 4,	3	3
Alternative 3	1, 2, 4, 5	1	2
Alternative 4		5	5
Alternative 5	1, 2, 4,	2	1

Figure 6. Results of the multicriteria analysis.

Alternatives 4 and 5 involve the inclusion of additional pasture. Alternative 4 uses the permanent approach to pasture additions and a wheat/fallow rotation on remaining cropland (see figure 5). Flexibility is poor with this production plan for obvious reasons but erosion control is excellent because of the additional grass cover. Note that by expanding the pasture base, the unfenced 14.9 hectares of "wasteland" now becomes usable pastureland. Alternative 5 uses the temporary approach to pasture additions and a wheat/fallow and sunflowers rotation on remaining cropland. Flexibility is excellent in this production plan but erosion control is poor because of all of the exposed soil.

If we view the results of these alternatives (see figure 6), we see that Alternative 3 dominates in the PROMETHEE results with Alternative 5 ranked second. Meanwhile, the weighted average method views Alternative 5 as the best with Alternative 3 second. A quick look at the actual weighted average calculations presents a clear picture of the reason for this change in order (see figure 7). The weather reduction criterion carries with it a very high weighting factor. Alternative 3 along with Alternative 2 perform very poorly in this criteria area and are penalized greatly in the weighted average calculations. A decision needs to be made about how big we want this influence to be on the results.

5. SUMMARY AND DISCUSSION

The *Agland Decision Tool* was built to provide a multicriteria comparison of various agricultural production plans on the author's 129.5-hectare

Weighted Average

Criteria (*j*)	Relative Importance Ranking	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5	
		Rating (1 to 5)	Combined Rating	Rating (1 to 5)	Combined Rating	Rating (1 to 5)	Combined Rating	Rating (1 to 5)	Combined Rating	Rating (1 to 5)	Combined Rating
Landlord Returns	7	2.0	13.8	3.8	26.6	5.0	35.0	1.0	7.0	2.8	19.9
Tenant Returns	2	1.0	2.0	2.8	5.6	4.2	8.3	3.7	7.4	5.0	10.0
Weather Reduction	6	4.0	23.9	1.0	6.2	1.0	6.0	5.0	30.0	4.5	26.8
Flexibility	5	3	15	4	20	4	20	1	5	5	25
Capital Outlay	4	5.0	20.0	5.0	20.0	5.0	20.0	1.0	4.0	4.9	19.5
Labor Requirements	1	5.0	5.0	4.2	4.2	3.3	3.3	4.5	4.5	1.0	1.0
Erosion Control & Sustainability	3	2	6	3	9	4	12	5	15	1	3
Total Desirability Rating			79.71		82.52		92.64		57.90		102.24

Figure 7. The calculations for the multi-criteria analysis using the weighted average method.

Payoff Matrix

Criteria	Alternatives 1	2	3	4	5
Landlord Returns	2687	3490	4021	2259	3073
Tenant Returns	4388	5476	6322	6051	6832
Weather Reduction	614	1474	1485	319	475
Flexibility	Good	Very Good	Very Good	Poor	Excellent
Capital Outlay	0	0	0	17000	500
Labor Requirements	231	267	305	255	405
Erosion Control & Sustainability	Fair	Good	Very Good	Excellent	Poor

Figure 8. The payoff matrix for the five alternatives under consideration.

property. The program allows up to five different production plans to be compared with one another using the PROMETHEE I, PROMETHEE II, and weighted average ranking methods. It was clear from the results that the two best production plans were Alternatives 3 and 5. Alternative 3 was an intense three crop rotation with the present pasture situation unchanged. Alternative 5 involved a temporary expansion of the pasture base using an annually seeded crop and temporary fencing. Alternative 3 provided very good revenue for both the landlord and the tenant (see figure 8). However, it carried with it significant exposure to adverse weather events affecting crop production and, thus, returns.

Meanwhile, Alternative 5 has a smaller return to the landlord and a very poor rating in erosion control and sustainability. These are tradeoffs for much less exposure to adverse weather losses. The weighting factors on the criteria are those established by the landlord/author. Therefore, they obviously look out for the landlord's interests first. It is easy to see how Alternative 3 could outrank Alternative 5 in PROMETHEE due to the significantly higher returns to the landlord. However, in the weighted average method, the poor result in regards to weather for Alternative 3 harms its standing enough to push Alternative 5 to the forefront. By using these two different decision making methods, it clarifies where the real decision/trade off lies.

The *Agland Decision Tool* has proven to be a valuable aid in decision analysis for this agricultural property. The landlord and the tenant intend to continue to use it in the future to identify and compare distinct production alternatives. It also serves as a prototype for the future development of production agriculture multicriteria decision support tools.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Brans, J.F., Ph. Vincke, and Mareschal, B., 1986. How to select and how to rank projects the PROMETHEE method. *European J. Oper. Res.*, 24:228-238.

Raju, K.S. and C.R.S. Pillai, 1999. Multicriterion decision making in river basin planning and development. *European J. Oper. Res.,* 112:249-257.