Strategies for agricultural growth

CHOOSING BETWEEN AGRICULTURAL INVESTMENT OPPORTUNITIES IN THE FREE STATE PROVINCE OF SOUTH AFRICA: A MULTIPLE CRITERIA ANALYSIS

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Abstract

Since the abolishment of Apartheid after 1994, one of the major sectors earmarked by the South African government to correct the injustices of the past, to improve inclusion, job creation and food security is the Agricultural sector. Various land reform programmes was initiated but the success rate was very low due to various reasons. One initiative was to create "master plans" for agricultural development on a provincial basis. These plans includes the identification and selection of possible agricultural production enterprises for implementation. A total of 13 possible enterprises was identified in the Free State province and a multiple criteria approach was used to rank the best fitting combination of enterprises given the specified goals/criteria. The results show that extensive beef and sheep production and intensive vegetable production is the enterprises that is most likely to improve the success of agricultural development, and by doing so, improve the welfare of the province

Keywords: Agricultural development, selection criteria, multiple criteria analysis

1. Introduction

The end of the Apartheid era in South Africa resulted in a lot of focus and energy being spent on rectifying the injustices of the past. The fact that a large proportion of all households in South Africa, especially in the rural regions, is still food insecure resulted in the agricultural sector to be ear-marked as having the potential to assist disadvantaged communities in order to create jobs and ensure food security. In fact, Biaphethi and Jacobs (2009) suggest that agricultural development can play an important role in reducing the

vulnerability of food insecure households, improving livelihoods and helping to mitigate high food price inflations.

As a result, large amounts of taxpayers' money have already been invested in agricultural development initiatives in South Africa as stipulated and outlined in the National Development Plan. However, the low success rate of these projects has increased pressure on government departments to deliver on their promises made, as more and more productive agricultural land has been virtually taken out of production. Recent government policies to fast track the expropriation of land will therefore only amplify the low success rate of agricultural development.

The failures of past agricultural development initiatives mainly revolve around human, institutional, infrastructure and natural resource endowments, with most of these factors being interrelated (Van der Merwe, 2012). According to Magingxa (2006), the formulation of workable development plans/projects can serve as a means to address the interrelated factors that inhibit agricultural development.

These development plans are based on certain enterprises that is deemed fit for production due to factors such as the availability of natural resources, profitability and entry barriers such as capital expenditure. Khapayi and Celliers (2016) is of a similar opinion by stating that many developing farmers face difficulties in accessing formal agricultural markets due to poor financial and social capital, limited access to credit and high costs that impacts on the profitability of the enterprise. Therefore, choosing the right enterprise for development projects is of critical importance.
A decision support system that will guide budget allocation for agricultural development initiatives is sorely needed. This paper will therefore attempt to provide a framework on how multiple criteria analysis (MCA) can be used as a decision support tool that will ensure optimal budget allocation for agricultural development. The Free State Province (FSP) is used as a case study to illustrate the potential of the model.

In order to illustrate how multiple criteria analysis could be used by government to ensure optimal budget allocation, the paper will start with a background, i.e. the region and the development of agricultural development plans for the selected region. This will be followed by a discussion on the model framework – algorithms and criteria development,

while the fourth section will deal with the results. The article will conclude with a summary of the results whereupon recommendations will be made.

2. Methodology

2.1. Overview of study and data

The development plan for the FSP, encompasses best practice models, resource audits, spatial planning database, land use options/models, the listing of economic opportunities and viable development projects, and focus on sustainable agricultural development in the FSP. The project was commissioned by the Free State Department of Agriculture (FSDARD).

The main focus is on the creation of an enabling environment for agricultural development as well as the realisation of specific pilot projects based on the different enterprises identified. Based on the natural resource audit and associated economic opportunities, a total of thirteen agricultural enterprises have been identified which can potentially improve agricultural development and economic growth in rural areas. For each of these, a detailed business plan was developed. Within these business plans the availability of natural resources, profitability and capital and operating expenditures was calculated. The enterprises identified includes:

- Poultry
  - Layers
  - Broilers
- Wildlife production
- Livestock production
  - Sheep/mutton
  - Beef
- Vegetables
  - Spinach
  - Potato
  - Onion
  - Cabbage
  - Carrot

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- Grain and oilseeds
  - Maize
  - Soybean
  - Sunflower seed

As mentioned, choosing the right enterprise for development projects is of critical importance. Therefore, a decision support system that will guide these decisions and assist in budget allocation for agricultural development initiatives is sorely needed. Ranking these alternative options are however difficult as they differ in a number of ways. Using a scientific method to choose between these alternatives can take into account all the factors and assist in the decision making process to improve budget allocation.

When choosing between alternatives, a number of conflicting factors need to be considered. Hajkowicz (2006) highlighted that when considering conflict analysis mainly four economic evaluation frameworks are available, which include: the cost-benefit analysis (CBA), cost effectiveness analysis (CEA), cost utility analysis (CUA) as well as the MCA. According to Hajkowicz (2006), the process of selecting the most appropriate framework will depend largely on the valuation of benefits. If benefits are adequately measured in monetary units, then CBA provides an appropriate framework. If not, the analyst will need to contemplate CUA or non-market valuations (NMV).

MCA is likely to be the most suitable framework if there is no monetary cost data available on which to rank decision (Hajkowicz, 2006). Marinoni, Higgins and Hajkowicz (2008) were of the same view, arguing that MCA is an evaluation framework which can be used to rank or score the performance of decision options e.g. policies, projects, locations etc. against multiple objectives in different units. Therefore, based on this, a MCA model was developed to rank the identified development opportunities for the FSP.

2.2. Model

The MCA methodology in this study makes use of the multilevel criterion and the 0-1 criterion. The reason for using the 0-1 and the multilevel criteria is that the 0-1 criterion is characterised by an infinite discriminating power while the multilevel criterion depends on the difference in evaluation scores and is sufficient to accomplish the desired goals.

Essential in the calculation process of the preference function is the establishment of weights for the relevant criteria. Specified criteria have different levels of importance and subsequently cannot be directly compared with each other. This problem can be overcome with the establishment of weights for each criterion which make it possible to compare criteria with different levels of importance with each other. After the weights have been established for each criterion, each enterprise will be weighed using the preference functions. In order to determine the exact relationship between the two alternatives, a PIR test is introduced. The PIR test incorporates indifference and incomparability thresholds in order to distinguish between preferences. A schematic presentation of the PIR sensitivity test can be found in Van Huylenbroeck, (1995).

2.3. Establishment of weights

Preference scores have to be weighted according to their relative importance. The conflict analysis method (CAM) information on the hierarchy of the criteria can be obtained in three ways depending on the type of data available, namely:

- The decision maker is able to give quantitative weights: these are rescaled between 1 and 100;
- he may not be able to give a priority order: in this case the decision maker is asked to compare the criteria two by two, and the weights are derived from the eigenvector of the pairwise comparison matrix;
- He is only able to give a ranking order: in this case the expected value of the weights is calculated.

If the decision maker is only able to give quantitative weights, as in this case, Van Huylenbroeck (1995) states that two approaches are possible. The first approach is applied in the "ORESTE" method where the ranking order information of the priorities is combined with the information on the criterion scores in a distance function. However, this is a rather complicated and arbitrary method. Van Huylenbroeck (1995) further explains that the estimation of the expected average value of the g_w-factor is a more theoretically sound way. On the basis of a uniform distribution of weights, it can be proved that the expected average value of the weights fulfilling the conditions imposed by the ordinal rank is given by the following equation:

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$$g_{w} = \sum_{i=k}^{n} \left(\frac{1}{i}\right)$$

With:

k = priority level or ranking of criterion j (with k = 1 for the most important and k = n for the least important criterion).

Modifications to this formula make it possible to handle ranking orders with ties (by multiplying the weight factor of order *k* by the number of times this ranking order occurs) or with a degree of difference (Van Huylenbroeck, 1995). Based on this, the weights of each sub-criterion are calculated according to their priority ranking. Stakeholders were consulted in an attempt to determine this priority list (see Table 1). For example, job creation was identified as a high level priority criterion and was subsequently included as a priority level 1 criterion with a weight of 0.1493. On the other hand, the use of existing state assets were identified as a low priority level criterion and was included as a priority level 5 criterion with a weight of 0.0299 (see Table 2). Weights calculated by using their priority levels will subsequently be used in the equation discussed in section 3.1 in order to determine the preference function which will indicate the preference of *a* over *b* and *b* over *a.*

2.4. Development of criteria

Balyamujura (1995) suggested that the basic aim of MCA is to rank the actions that can be taken to solve a problem to which several alternatives but conflicting choices exist. The ranking is based on set goals or criteria. Moreover, Fischer, Granat and Makowski, (2010) suggest that when evaluating the performance of alternative choices (i.e. development plans), often the specification of a single objective function does not adequately reflect the preferences of decision makers. Fischer *et al.,* (2010) suggests that when decision makers deal with practical resource complexities, their preferences are normally of a multi-objective nature; therefore all factors impacting on agricultural development in the FSP need to be considered when developing a multi-objective MCA model.

Considering the preferences of decision makers in the FSP, a MCA model was developed that depicted a trade-off between economic, environmental and social factors. Within the background of budget constraints, it is of the utmost importance for government that

agricultural development should be conducted in a sustainable manner if they are to deliver on promises made.

The Chair in International Agricultural Marketing and Development (CIAMD, 2001) reported that in order to determine the optimal trade-off between the economic, environmental and social objectives, the following criteria need to be considered (Table 1):

- Economic benefits to the province.
- The Long-term sustainability of the project.
- The future prospects of each plan
- The degree of local resource utilisation

The criteria, which are to be optimised in order to attain an increase in welfare, are listed in Table 1. The respective ranking order illustrating the priority level of each criterion is also included in Table 1. This criteria were used to evaluate the different alternatives and to determine the best development plan under the set objectives.

Table 1: Rank order of goals or criteria

Criterion	Comment	Rank (Scenario 1)
Job creation	Number of jobs created	1
Income generation	Annual income generated per beneficiary	1
Annual contribution to GGP	Total turnover of project per beneficiary	1
Economic sustainability	Amount of additional support needed	2
Social sustainability	Technicality of production	2
Environmental sustainability	Natural grazing, water use, fertilizer and pesticide use and waste generated	2
Economic growth potential	Total value generated by the enterprise in the economy	2
Potential for replication	Capital costs and size of area used	3
Adaptability to change	Fixed assets and fluctuations in changing markets	3
Use of existing state assets	Potential to use existing infrastructure	3
Use of local resources	Potential to use local resources	4
Use of external resources	Potential to use external resources	4
Degree of institutional support	Degree of institutional support	5

3. Results

The criterion used to compare the different production enterprises in terms of a set criterion was obtained from a study done in the Eastern Cape Province. The criterion was modified according to the inputs from decision makers in the FSP. Important information was

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acquired from these workshops, which assisted in determining the values of each enterprise in terms of the respective criteria. Values were awarded depending on the priorities of decision makers, which reflect on the improvement of the welfare of the communities and the conservation of the province for future use. Each enterprise was awarded a value in terms of the potential employment opportunities created. In Table 1, the factors used to determine the value of each criterion is discussed.

These values were transformed into a percentage value in order to compare the enterprises with each other. The enterprises generating the highest value in terms of a criterion were awarded a percentage value of 100. The remaining received values accordingly. The ranking order may differ, depending on the priorities of the decision maker at a specific time (see Table A1).

However, before the enterprises can be ranked, weights need to be assigned to the identified criteria (see Table A1). These weights have been calculated based on the equation described in section 2.3.

Results obtained can be sensitive to modifications to either the criterion scores, ranking of the criteria or nature of preference function used. Subsequently, sensitivity of modifications can be illustrated by using the following:

- Changing the preference function from the multilevel criteria to the 0-1 criteria and
- by changing the ranking order (weights) of the criteria (shown in Table 2)

The results of the sensitivity test can be seen in Figures 2 and 3 respectively. In the CAM a value of 3.5 is applied for β, 7.5 for C* and values of 5 and 1 for $u1$ and $u2$ respectively.

3.1. Conflict analysis: multilevel preference function (base scenario)

Table A2 illustrates the multilevel preference indicators as used in the conflict analysis. These values already incorporate the relative weights of the criteria and are a fair reflection of the preference of each business plan in relation to the other. However, these values are still used in the PIR sensitivity test to determine the exact relationship between two alternatives.

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Table A3 depicts the values gained from analysing the values in Table A1 with the conflict analysis method (CAM). The goal of the CAM is to determine the relationship between two alternatives, and the values in Table A2, is the first step in achieving this goal. The following step is to determine the exact relationship between two alternatives. This step entails using the PIR-sensitivity test.

Table A3 reflects on the results from the PIR sensitivity test and therefore shows the exact relationship between two alternatives. In other words, Table A3 illustrates the preference of each business plan in relation to the other business plans with: '!' that reflects on indifference between the plans, R on incomparability, > on a weak preference and >>> which reflects a strong preference.

For example, from the results, Wildlife is reportedly indifferent compared to Broilers. Furthermore, Potatoes are reported to be incomparable with Maize, with Sheep that is likely to yield higher returns than Onions. A strong preference for Cabbage is reported when compared to Layers etc.

3.2. Conflict analysis: 0-1 criterion function (sensitivity test)

Similar to the previous section, Table A4 illustrates the 0-1 preference indicators as used in the conflict analysis. These values already incorporate the relative weights of the criteria and are a fair reflection of the preference of each enterprise. Values obtained in Table A4, is the first step in determining the relationship between two alternatives. The following step will be to use these values in the PIR sensitivity test and to determine the exact relationship between two enterprises. The exact relationship between two enterprises is depicted in Table A5. In other words, Table A5 illustrates the preference of each business plan in relation to the other business plans. A description of the abbreviations in Table A5 can be found in the annexure. Following is the results obtained.

3.3. Conflict analysis: multilevel preference function with a different priority ranking order of the criteria (sensitivity test)

In order to illustrate the sensitivity with regard to a change in the ranking order of the criteria, different priority levels of criteria were identified (see Table 2). This was done by

consulting additional stakeholders and is merely an attempt to illustrate the sensitivity of a change in the priority levels of the criteria and to get another perspective on the ranking preferences. Additionally, the inclusion of this scenario in determining the final ranking order gives a better representation of the preferences of all the stakeholders in the province. A preference function similar to that used in the base scenario (i.e. multilevel preference function); thus the change in results is due to the change in the ranking order of the criteria. The new weights awarded to each criterion are as a result of a change in their priority ranking order (see Table 2).

Table 2: New weights awarded to each sub criteria.

	Weight	Changed priority ranking order	Previous priority ranking order
Job creation	0.1493	1	5
Income generation	0.0746	2	5
Contribution to GGP	0.1493	1	1
Economic sustainability	0.0746	2	2
Social sustainability	0.0746	2	1
Environmental sustainability	0.0746	2	3
Economic growth potential	0.1493	1	2
Potential for replication	0.0372	4	1
Adaptability to change	0.0498	3	3
Use of existing state assets	0.0299	5	4
Use of local resources	0.0498	3	5
Use of external resources	0.0372	4	5
Degree of institutional support	0.0498	3	3

Table A7 shows the preference indicators of the multilevel criteria function with different criteria. To determine the exact relationship between two alternatives, the preference indicators are incorporated into the PIR sensitivity test (see Table A8). Examples on how to interpret the results in Table A8 can be found in the annexure.

3.4. Summary of results

Figure 1 reflects the ranking order that was obtained using the multilevel criterion function (base scenario). Considering all these criteria as well as the ranking order, cabbage, carrots and beef (Tier 1) are ranked as the best alternatives, with spinach, sheep and wildlife (Tier 2) ranked as second best. The enterprises that has the least potential in this case is sunflower, layers and broilers (Tier 4). Based on the ranking, capital investments into intensive vegetables, beef, sheep and game production are likely to yield the highest returns. However, the preference function combined with the criteria is not sufficient to

give a clear representation of which business plans are more preferred when compared to the others. This is evident from the fact that no clear distinction can be drawn between some of the alternatives. Consequently, the 0-1 criterion function was also applied and considered.

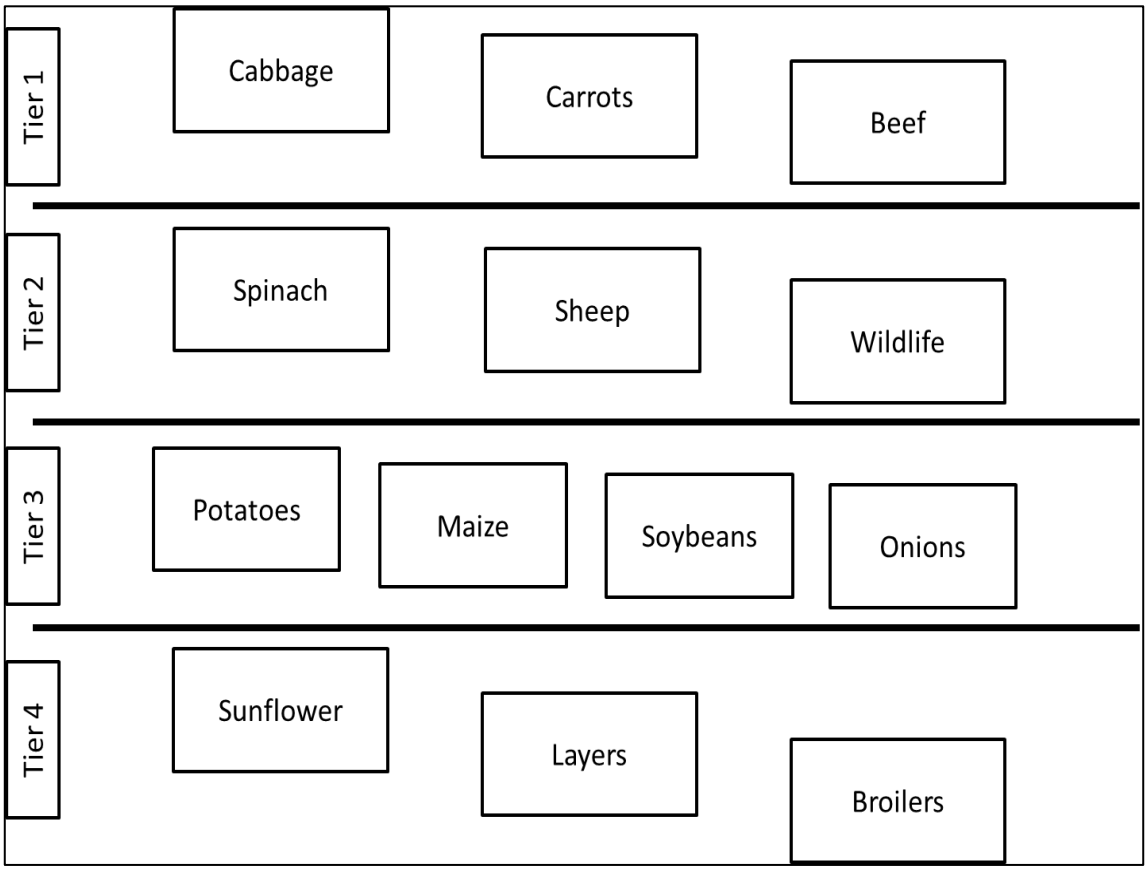

Figure 1: Scenario 1 (multilevel preference function).

Figure 2 is a representation of the ranking order obtained by using the 0-1 preference function. The scenario used the same criteria as was used for the multilevel preference function analysis. Hence the sensitivity of changes in the preference functions was tested by changing the multilevel preference function to the 0-1 preference function. The change in preference functions resulted in beef and sheep reportedly being the best opportunities to pursue under the set criteria. cabbage, carrots, sunflower, spinach and maize follow this. Broilers and layers are again ranked as the enterprises with the least potential.

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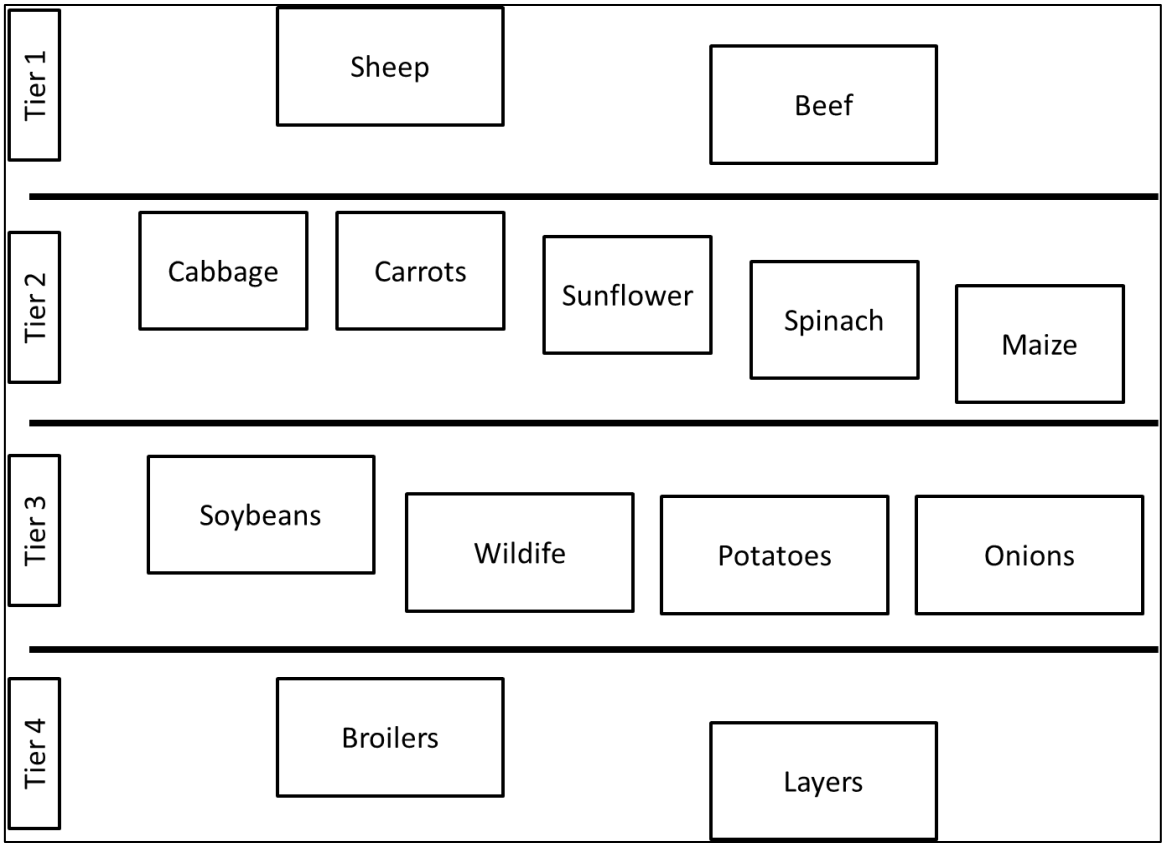

Figure 2: Scenario 2 (0-1 preference function)

Figure 3 illustrates the results obtained using the multilevel preference function with different priority rankings for the set criteria (see Table 8 for the change in priority rankings). New priority levels were identified for each criterion and weights were calculated accordingly.

When comparing Figure 3 with the previous scenarios (depicted in Figure 1 and Figure 2), it becomes evident that a change in the priority ranking of the criteria does not have a significant impact on the results. For example, cabbage, beef and carrots are again ranked as the best alternatives while broilers, layers, potatoes and sunflowers are lower ranked opportunities.

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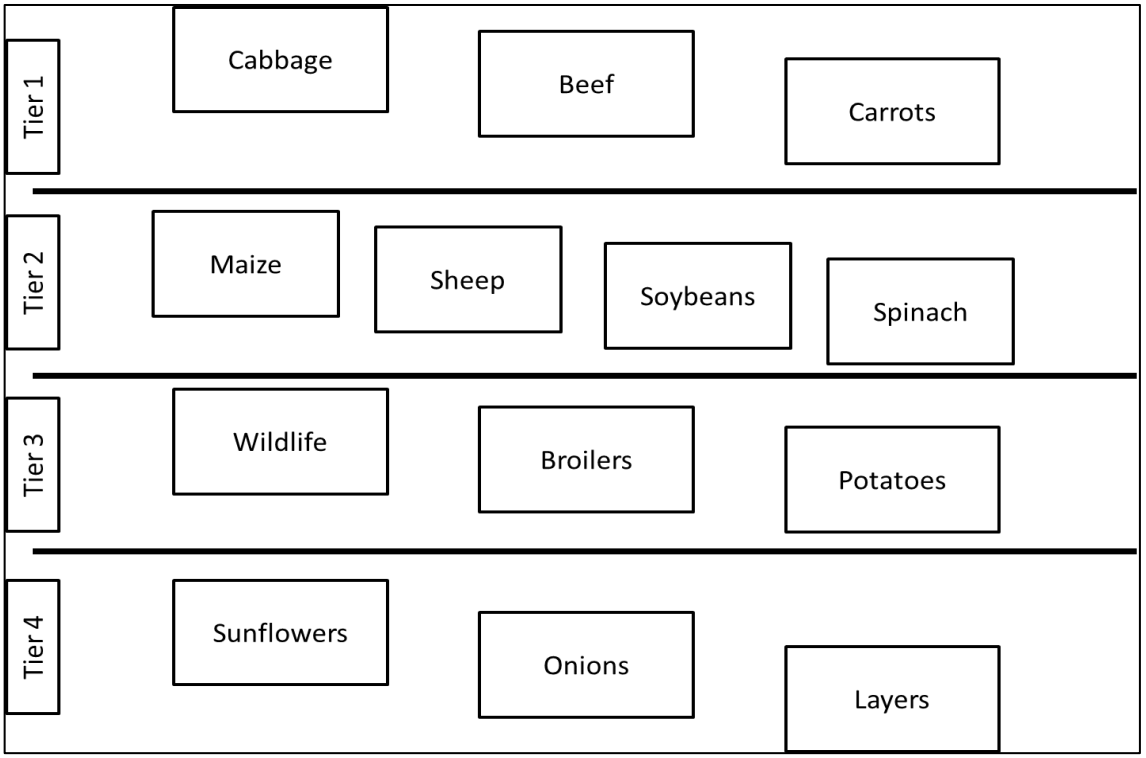

Figure 3: Scenario 3 (multilevel preference function with different ranking of criteria).

Considering all these analyses, enterprises like cabbage-, beef-, sheep- and carrot production remain highly likely to yield the highest returns in terms of the objective. Alternatives such broiler-, layer-, onion- and sunflower production are likely to yield the lowest returns in terms of the set criteria.

These alternatives yield the highest returns because they consistently addresses the goals as set out in Table 1. Thus, one might argue that when faced with a budget constraint, investing money or allocating funds towards intensive vegetable production such as carrots, cabbages, extensive beef and sheep production will most likely achieve the set objective (i.e. welfare improvement while conserving the province for future use).
Note that these results are based on the outcomes that will result from the business concepts and the size of the enterprise/venture.

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4. Conclusion

It is evident from the results that the criteria and the ranking priorities have a significant influence on the outcome of the MCA. However, when considering all relevant scenarios, one might conclude that extensive beef and sheep production and intensive vegetable production is the enterprises that is most likely to improve the success of agricultural development, and by doing so, improve the welfare of the province. In other words, these enterprises have the ability to successfully address a combination of the goals as set out in Table 1.

On the contrary, although the opportunities exist to engage broiler-, layer and sunflower production in the province, they are evaluated as the enterprises which are the least likely to achieve the set objectives.

In must be mentioned that the business concepts that is used for each enterprise plays a significant role in how each enterprise satisfies the criteria, i.e. number of jobs that will be created by the venture, capital required, income generated etc. If this is changed, the ranking order of the enterprise will also change. The ranking order depicted in this study is therefore only valid for the given business concepts and the size of operations.

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Annexure

Table A1: Data for comparison of the different business plans

	Weight	Priority ranking	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soy	Sunflower
Job creation	0,15	1	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Income generation	0,15	1	92,2	100,0	92,8	99,2	91,3	91,2	91,2	91,2	91,2	91,2	91,2	91,2	91,2
Contribution to GGP	0,05	3	40,9	49,0	34,4	51,6	40,3	5,1	16,7	60,5	6,9	3,9	100,0	99,5	34,5
Economic sustainability	0,15	1	0,5	0,1	2,9	1,3	1,5	75,0	44,1	11,5	115,4	100,0	1,8	1,4	3,6
Social sustainability	0,07	2	20,0	80,0	80,0	20,0	100,0	40,0	40,0	40,0	40,0	40,0	50,0	50,0	50,0
Environmental sustainability	0,07	2	20,0	100,0	100,0	20,0	100,0	40,0	40,0	40,0	40,0	40,0	50,0	50,0	50,0
Economic growth potential	0,04	4	25,4	18,5	18,5	100,0	82,3	0,0	16,6	3,8	0,7	1,6	73,7	15,9	9,8
Potential for replication	0,05	3	56,7	0,1	1,6	57,2	0,9	65,0	38,2	9,9	100,0	86,7	1,2	1,0	2,4
Adaptability to change	0,07	2	10,0	100,0	100,0	10,0	100,0	70,0	70,0	70,0	70,0	70,0	50,0	50,0	50,0
Use of existing state assets	0,03	5	40,0	40,0	100,0	40,0	100,0	50,0	50,0	50,0	50,0	50,0	70,0	70,0	70,0
Use of local resources	0,07	2	60,0	50,0	100,0	60,0	100,0	60,0	60,0	60,0	60,0	60,0	70,0	70,0	70,0
Use of external resources	0,04	4	33,3	25,0	100,0	33,3	100,0	33,3	33,3	33,3	33,3	33,3	50,0	50,0	50,0
Degree of institutional support	0,05	3	0,4	0,1	2,5	1,2	1,3	65,0	38,2	9,9	100,0	86,7	1,6	1,2	3,1

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Table A2: Multilevel preference intensity indicators.

	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soy	Sunflower
Layers	0,00	3,00	2,37	0,00	2,11	2,06	1,87	2,35	1,98	2,06	2,09	2,35	2,69
Wildlife	13,37	0,00	1,29	12,34	1,24	9,92	9,07	8,26	9,84	9,92	7,87	7,94	8,61
Sheep	17,83	6,38	0,00	17,66	0,38	13,60	12,74	12,46	13,51	13,60	10,83	10,96	10,89
Broiler	3,24	5,21	5,44	0,00	3,71	5,16	4,98	5,09	5,08	5,16	3,54	5,08	5,80
Beef	21,71	9,60	3,20	19,95	0,00	16,41	15,56	15,06	16,33	16,42	11,80	13,35	13,71
Spinach	16,08	13,57	12,16	15,95	12,39	0,00	5,20	10,70	0,00	0,05	13,39	13,46	13,11
Potato	11,54	8,37	6,96	11,42	7,19	0,85	0,00	5,84	0,77	0,85	8,20	8,28	8,09
Onion	7,75	3,28	2,39	7,25	2,41	2,07	1,56	0,00	1,99	2,07	2,70	2,76	3,34
Cabbage	22,88	20,37	18,96	22,74	19,19	6,88	11,99	17,49	0,00	2,70	20,19	20,25	19,91
Carrot	20,29	17,78	16,37	20,15	16,60	4,25	9,41	14,90	0,02	0,00	17,60	17,67	17,32
Maize	10,52	5,93	3,80	8,73	2,19	7,80	6,95	5,73	7,72	7,80	0,00	1,62	4,03
Soy	9,16	4,38	2,32	8,66	2,11	6,25	5,42	4,18	6,17	6,25	0,00	0,00	2,48
Sunflower	7,37	2,93	0,12	7,25	0,34	3,77	3,10	2,63	3,69	3,78	0,28	0,35	0,00

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Table A3: Results of the conflict analysis for the multilevel criterion function

First Action P(a,b)	Second Action P(b,a)												
	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soybean	Sunflower
Layers	!												
Wildlife	<<<	!											
Sheep	<<<	!	!										
Broiler	!	>	>	!									
Beef	<<<	<<<	!	<<<	!								
Spinach	<<<	<	R	<<<	>	!							
Potato	<<<	R	>	<<<	>	!	!						
Onion	<<<	>	>	!	>	>	!	!					
Cabbage	<<<	<<<	<	<<<	R	!	<<<	<<<	!				
Carrot	<<<	<	<	<<<	R	!	<<<	<<<	!	!			
Maize	<<<	>	>	<<<	>	>	R	!	>	>	!		
Soybean	<<<	>	>	<	>	>	>	!	>	>	!	!	
Sunflower	!	>	>	!	>	>	>	!	>	>	!	!	!

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Table A4: 0-1 preference intensity indicators.

	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soybean	Sunflower
Layers	0,00	3,00	2,37	0,00	2,11	2,06	1,87	2,35	1,98	2,06	2,09	2,35	2,69
Wildlife	13,37	0,00	1,29	12,34	1,24	9,92	9,07	8,26	9,84	9,92	7,87	7,94	8,61
Sheep	17,83	6,38	0,00	17,66	0,38	13,60	12,74	12,46	13,51	13,60	10,83	10,96	10,89
Broiler	3,24	5,21	5,44	0,00	3,71	5,16	4,98	5,09	5,08	5,16	3,54	5,08	5,80
Beef	21,71	9,60	3,20	19,95	0,00	16,41	15,56	15,06	16,33	16,42	11,80	13,35	13,71
Spinach	16,08	13,57	12,16	15,95	12,39	0,00	5,20	10,70	0,00	0,05	13,39	13,46	13,11
Potato	11,54	8,37	6,96	11,42	7,19	0,85	0,00	5,84	0,77	0,85	8,20	8,28	8,09
Onion	7,75	3,28	2,39	7,25	2,41	2,07	1,56	0,00	1,99	2,07	2,70	2,76	3,34
Cabbage	22,88	20,37	18,96	22,74	19,19	6,88	11,99	17,49	0,00	2,70	20,19	20,25	19,91
Carrot	20,29	17,78	16,37	20,15	16,60	4,25	9,41	14,90	0,02	0,00	17,60	17,67	17,32
Maize	10,52	5,93	3,80	8,73	2,19	7,80	6,95	5,73	7,72	7,80	0,00	1,62	4,03
Soybean	9,16	4,38	2,32	8,66	2,11	6,25	5,42	4,18	6,17	6,25	0,00	0,00	2,48
Sunflower	7,37	2,93	0,12	7,25	0,34	3,77	3,10	2,63	3,69	3,78	0,28	0,35	0,00

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Table A5: Results of the conflict analysis for the 0-1 criterion function.

First Action P(a,b)	Second Action P(b,a)												
	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soybean	Sunflower
Layers	!												
Wildlife	<<<	!											
Sheep	<<<	!	!										
Broiler	!	>	>	!									
Beef	<<<	<<<	!	<<<	!								
Spinach	<<<	<	R	<<<	>	!							
Potato	<<<	R	>	<<<	>	!	!						
Onion	<<<	>	>	!	>	>	!	!					
Cabbage	<<<	<<<	<	<<<	R	!	<<<	<<<	!				
Carrot	<<<	<	<	<<<	R	!	<<<	<<<	!	!			
Maize	<<<	>	>	<<<	>	>	R	!	>	>	!		
Soybean	<<<	>	>	<	>	>	>	!	>	>	!	!	
Sunflower	!	>	>	!	>	>	>	!	>	>	!	!	!

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Table A7: Multilevel preference intensity indicators with a different priority ranking order of the criteria.

	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soybean	Sunflower
Layers	0,00	2,85	2,90	0,00	1,61	6,58	4,07	3,61	6,31	6,54	1,54	2,55	3,85
Wildlife	11,94	0,00	1,94	10,71	1,39	13,52	10,51	8,43	13,25	13,48	6,51	6,79	8,98
Sheep	15,37	5,33	0,00	15,27	0,22	15,84	12,83	12,31	15,57	15,80	9,27	9,59	10,09
Broiler	9,55	11,16	12,34	0,00	5,01	16,04	13,54	11,94	15,77	16,00	4,72	10,89	13,32
Beef	24,08	14,06	9,15	17,46	0,00	24,26	21,25	20,10	23,99	24,22	11,07	17,24	18,50
Spinach	10,97	8,82	7,75	10,88	7,89	0,00	3,31	6,81	0,00	0,14	8,56	8,61	8,39
Potato	8,15	5,51	4,44	8,08	4,58	3,00	0,00	4,87	2,74	2,97	5,25	5,37	5,80
Onion	7,49	3,23	3,72	6,28	3,23	6,30	4,67	0,00	6,03	6,27	1,75	1,79	4,34
Cabbage	15,30	13,15	12,08	15,21	12,22	4,60	7,64	11,14	0,00	1,98	12,89	12,93	12,71
Carrot	13,65	11,50	10,43	13,56	10,57	2,85	5,99	9,49	0,09	0,00	11,24	11,29	11,07
Maize	17,63	13,51	12,88	11,26	6,41	20,26	17,26	13,96	19,99	20,23	0,00	6,25	13,79
Soybean	12,39	7,54	6,95	11,18	6,32	14,05	11,13	7,75	13,78	14,02	0,00	0,00	7,58
Sunflower	6,32	2,37	0,08	6,25	0,22	6,47	4,19	2,93	6,20	6,43	0,18	0,22	0,00

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Table A8: Results of the conflict analysis for the multilevel criterion function with a different priority ranking order of the criteria.

First Action P(a,b)	Second Action P(b,a)												
	Layers	Wildlife	Sheep	Broiler	Beef	Spinach	Potato	Onion	Cabbage	Carrot	Maize	Soybean	Sunflower
Layers	!												
Wildlife	<<<	!											
Sheep	<<<	!	!										
Broiler	R	R	R	!									
Beef	<<<	<<<	<<<	<<<	!								
Spinach	<	>	>	>	>	!							
Potato	<<<	>	>	>	>	!	!						
Onion	!	>	>	>	>	!	!	!					
Cabbage	<<<	R	>	R	>	!	<<<	<	!				
Carrot	<<<	R	>	R	>	!	!	<	!	!			
Maize	<<<	<<<	<	<<<	>	<<<	<<<	<<<	<	<	!		
Soybean	<<<	R	>	R	>	<	<<<	<<<	R	<	!	!	
Sunflower	!	>	>	>	>	>	!	!	>	>	>	>	!

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