The mathematical formulation and scheduling for creating a self sustainable vegetable food garden

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Executive Summary

The idea of this project is to optimize the operations of a community vegetable garden to produce enough food for a certain amount of people as well as achieve financial self sustainability.

The project looks at the operations of a community vegetable garden that is currently subsidised by a corporate partner and aims to optimise the resource usage, scheduling and operations to make it possible for the food garden to become self sustainable. A mathematical model was created in order to find an optimal solution for the problem. The area of soil given needs to produce the maximum amount of nutrients possible in order to make the vegetable garden self sustainable.

Linear programming were used to determine the amount and types of vegetables to plant each month, in order to maximize profits, reach financial sustainability and have a balanced meal each day. Agriculture provide a few complexities, but could be addressed using Industrial Engineering skills such as Operations Research, Business Accounting and Engineering Economics.

HEARTBEAT

Welcome to Heartbeat
Centre for Community Development

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Chapter 1

1 List of Abbreviations

OVC Orphaned and Vulnerable Children
CNPP Centre for Nutrition Policy and Promotion
GIS Geographical Information Systems

2 Background

Heartbeat is a Non-Profit (Reg: 015-242), Public Benefit (Reg: 18/11/13/4841) organization that helps 'Orphaned and Vulnerable Children' (OVC). Heartbeat was founded by Dr. Sunette Pienaar in 2000. They have a few projects that are running in different communities and Heartbeat offers support to the children in these communities.

Heartbeat is working according to 4 principles. They protect the rights of the children, encourage community participation, implement sustainable development, and build partnerships with people in these areas. At this moment Heartbeat has successfully partnered projects in 7 out of 9 provinces in South Africa.

Heartbeat uses 2 approaches to contribute to their programs. The first approach or leg of this project (for which this project will be used) is one that Heartbeat does on their own. With this leg of the project they reach more or less 4500 OVC. The first leg of this project includes several projects which are running to contribute to the positive transformation of the child in all aspects of his/her life. The different projects that are currently running are Material provision, Education, Children's empowerment, Rights and Access and Capacity building. The second leg of the project is a training and mentorship program, and reaches about 7000 OVC.

This project will focus on the program called Material provision. Heartbeat has 2 farms where they plant vegetables to feed the OVC in their communities. The plan for this project is to help these 2 farms become self sustainable. There are 2 sides to this project that have to be considered. The first objective is to feed the OVC with a balanced diet. The vegetables in the garden have to contain enough nutrients for the development of healthy children, which can be reached through a balanced diet and meal every day. The second objective is to sell the vegetables that are left after all the OVC are fed, to ensure that the food garden is financially sustainable. Both of these objectives have to be reached in order to make this project successful.

The 2 farms at Exxaro and Nellmapius are currently in development stages. These farms are very primitive at this stage with very few implements and labourers. They are not financially sustainable, and need the support and funding from Heartbeat.

If the goal of this project succeeds, Heartbeat can start to implement an optimized, self sustaining food garden that will be of great value to the community and the OVC. One of the very important principles of the implementation of this project will be to help people in order to help themselves.

Agriculture and management of natural resources have always been one of the most important aspects of human survival and welfare. 'Linear programming was originally used to solve farm planning problems which were deterministic and static.' (Kennedy 1986, p. 5)

3 Problem Statement

'An optimal policy has the property that, whatever the initial state and optimal first decision may be, the remaining decisions constitute an optimal policy with regard to the state resulting from the first decision.' (Kennedy 1986,p.30) The amount of return from harvesting crops depends on certain controllable as well as uncontrollable events. The controllable events are timing and density of planting, the timing of harvesting and the amount of maintenance inputs. The maintenance inputs include soil leaching, pesticides, herbicides, fertilizer and additional water provided. The uncontrollable events are the timing and amount of rainfall, and exposure to sunlight. (Kennedy 1986,p.30)

Heartbeat experiences problems in developing a self sustaining food garden. They do not have enough funds to pay laborers on a full time basis to maintain these gardens. They need to feed 4500 OVC, and need to generate enough funds to make this garden self sustainable. Heartbeat needs a mathematical model that will ensure that they use the optimal capacity and capability available.

The following question arises:

Can the area of a food garden be planned and divided in such a way to provide enough nutrients for a balanced meal each day throughout the year, as well as enough funds be generated to make the food garden self sustainable?

4 Literature study

4.1 About vegetables

According to French and US researchers (TUFTS UNIVERSITY HEALTH & NUTRITION LETTER 2006, p. 3) fruits and vegetables are the foods that provide the most nutrition for the price that you pay. After analyzing 637 different foods, they came to the conclusion that fruits and vegetables provide 'essential nutrients at a reasonable price.' Some of the best scoring fruits and vegetables in terms of 'nutrient density per dollar' are oranges, bananas, carrots, cabbage, tomatoes, celery, onions, cans of mixed vegetables and fruit juices. After fruits and vegetables came lean meats and dairy products, with desserts and sweets being the worst value for your money, in a nutrient to cost ratio.

Elise Golan, Hayden Stewart, Fred Kuchler and Diansheng Dong (2008, pp. 26-33) asks the following question: 'Can low-income Americans afford a healthy diet?' This question can be rephrased. For instance: Can South Africans being paid a minimum wage afford a healthy diet? The question if poor South Africans have a healthy diet isn't clear. In the case of America it is stated that the low-income households tend to have less nutritional diets than other households. This raises the concern about the affordability of healthy foods. The 'Centre for Nutrition Policy and Promotion' (CNPP) in America constructed several plans regarding the way their households eat at different income levels. The CNPP developed a mathematical optimization model to construct a diet taking into account eating patterns, while meeting the Federal Nutrition Guidelines and specific cost levels. This study showed that the low-income households can still benefit the maximum amount of nutrition. If this study was performed in South Africa, the outcome would probably have been extremely different, because the average income per capita is less in South Africa than in America.

4.2 Application of Industrial Engineering techniques and models in Agriculture

Derya B. O¨ zyurt and Matthew J. Realff (2002, pp. 13-33) combined a geographical information system and process engineering to design an agricultural industrial ecosystem. 'A methodology of systematically constructing an industrial ecosystem is presented'. (Derya B. O¨ zyurt and Matthew J. Realff 2002, p. 13) One of the main objectives they want to reach is to maximize the system benefit by generating optimal configurations for an industrial ecosystem. The benefit in this specific case is the revenue generated. For the implementation two computer tools were combined. These two tools are 'Geographical Information Systems' (GIS) and mathematical programming. This integrated approach requires industrial ecology concepts with industrial and systems engineering, environmental modeling, as well as graphical information. An overall methodology is developed to form an agricultural-industrial complex. One of their main problems is to find the basic cartographic data of a region given the location of production facilities, and the features impacting their connection. The information regarding temperature, pressure, impurity and time of year/phase must be available. The four main steps for successfully executing the optimal agro-industrial ecosystem are the following:

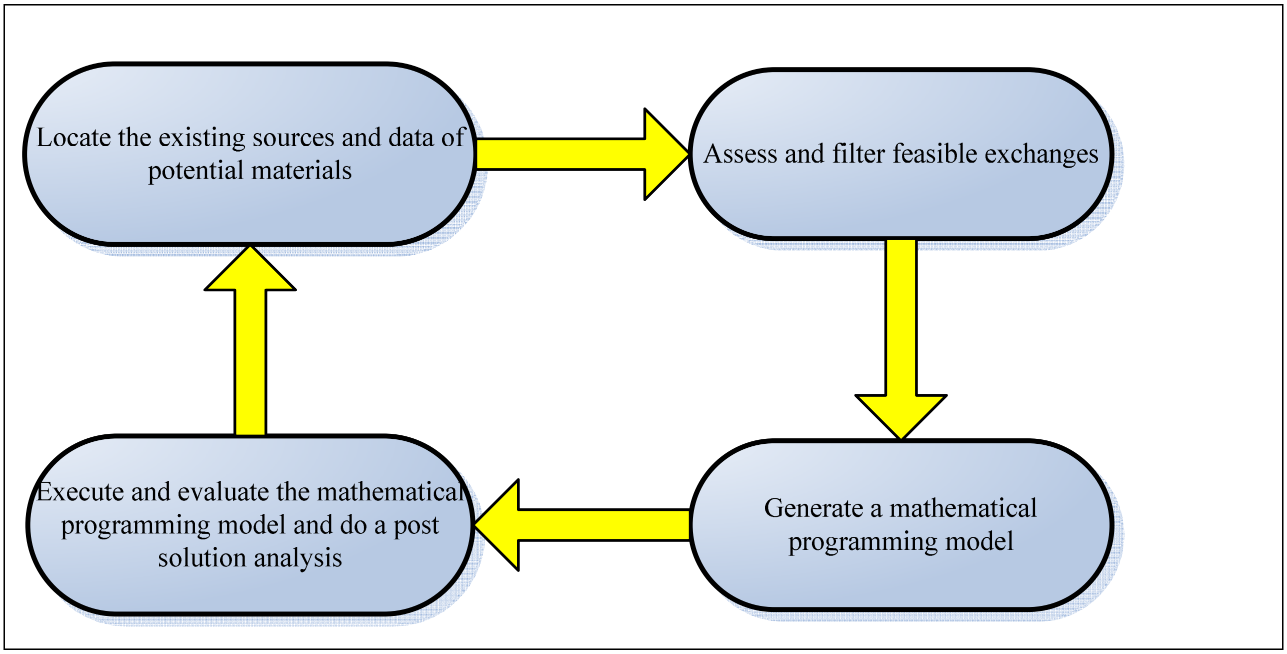


Figure:1 The above presentation is a summary of the four step plan for their project as according to Derya B. O¨ zyurt and Matthew J. Realff (2002, p. 16)

Sushi1 Pandey and and R.W. Medd (1990, pp. 115-128) developed the framework of a stochastic dynamic program to control the decision making about wheat in the southern parts of Australia. Their paper develops a 'stochastic multi-period decision model to analyse a continuous wheat cropping system infested by wild oats *(Avena fatua* L.1), in southern Australia.' (Sushi1 Pandey and and R.W. Medd 1990, p. 115) A dynamic programming model is combined with a bio economic simulation model to obtain a multi-period solution. Environmental effects cause uncertain crop yields and had to be modeled using optimal decision rules. Future profits and effects had to be taken into consideration as the decisions currently made will have an enormous effect on it. This means that their model couldn't be formulated as only a current period solution. The effects of risk also had to be modeled. In most cases only one source of risk is modeled at a time, and this is inappropriate. Models with multiple sources of risk have greater accuracy. If future losses are taken into account the amount of risk may be justifiable. They had to take into account the effects of multi-period weed control decisions, stochastic influences and the attitude of the farmers. Sushi1 Pandey and and R.W. Medd (1990, pp. 115-128) used dynamic programming to efficiently solve the maximization problem. One of the advantages of dynamic programming is that the risk elements can be incorporated more easily if it is compared to other programming methods. A global optimum solution could be found even while the objective function is discontinuous. The optimal solution for each stage was derived by dividing the total planning horizon into periods or stages. Each one of the stages has an effect on the next through the state variables. 'This requirement of dynamic programming is called the condition of Markovian independence (Nemhauser, 1966).' (Sushi1 Pandey and and R.W. Medd 1990, p. 118) The following dynamic programming recursive equation was used in their solution procedure:

$$V_t(SD_t, W_t) = \max_{X_t} [E\pi(SD_t, W_t, X_t) + E.V_{t-1}(SD_{t-1}, W_{t-1})] \ldots\ldots\ldots\ldots (1)$$

$V_t(SD_t, W_t)$	=	Optimal value function at stage 't' given seed density (SD) and weed density (W);
SD_t	=	seed density in the soil at time t
E	=	expectations operator
W_t	=	weed density at time t
X_t	=	herbicide dose
π	=	is the current profit if decision X is implemented

Equation (1) was derived from the work of Sushi1 Pandey and and R.W. Medd (1990, p. 117)

De Ridder, N.A. (1973, pp. 17-37) used models to solve agricultural development problems. 'Agricultural development is a complex undertaking because of the numerous factors involved, including those of a physical and non-physical nature.' Integration of physical, environmental, economical, and social factors encounters some difficulties, therefore sufficient data and exact methodologies are very important. 'The complexity of the problem has outgrown traditional problem-solving methods.' (De Ridder, N.A. 1973, pp. 17) The main idea of this article is to find optimal solutions by using a linear programming model of water supply, as well as developing a mathematical groundwater basin model. The unique feature of these two models is that the linear programming model can be used to test the validity of the groundwater basin model and the economic solution. The advances in science and technology during the last decades made it possible to adapt and apply some of the modern techniques and solve it with computerized models and simulations. To develop agriculture, or in the same sense any profession, a few aspects such as planning, management, and control are important. Of these phases, control is the most important as it is the monitored state of the development system. Firstly a system needs to have interrelated objects, actions, or procedures, rather than a bunch of loose parts. Secondly a model has to be developed to solve the problem. A model was constructed maximizing the net income of a governmental agency taking care of the distribution and supply of irrigation water. Maximization in this context means that the marginal returns should be greater or equal to the marginal costs.

Andrew J. Higgins and Stefan Hajkowicz (2007, pp. 459-471) presents a new adaptable mathematical programming framework that can be used on a variety of spatial explicit landscape problems such as land-use planning. 'We applied a hybrid greedy randomized adaptive search procedure (GRASP) to find solutions to the model.' (Andrew J. Higgins and Stefan Hajkowicz 2007, p. 459) There was a rapid increase in the previous two decades, in the literature of the application of mathematical programming methods, applied to spatially explicit landscape problems. The landscape is divided into a number of blocks, each represented by an integer decision variable. It often happens that the problem contains a large number of decision variables. One of the biggest challenges is to present a mathematical model that captures the 'real world', while being mathematically correct. Andrew J. Higgins and Stefan Hajkowicz aimed their land-use problem at achieving the best selection of parcels. Optimization models of land use problems sometimes have multiple objectives because of multiple benefits to industry. A multi-objective model was formulated. The first objective is the minimization of the cost, and the second is the maximization of the size of parcels formed. Different problems can be addressed by controlling the size, shape, and number of parcels formed by grid cells. The following problems can be solved by using the spatial modeling approach:

- Land usage for land owners.
- Transport costs to processing facilities.
- Capacity of processing facilities
- Mixtures of agricultural options for landscapes.
- Determining the most effective way of allocating financial resources.

4.3 Using area optimization on floor plans

Ting-Chi Wang and D.F. Wong (1990, pp. 180-186) presented an algorithm for the optimization of a problem they encountered concerning the area of a floor plan. ‘Experimental results indicate that our algorithm is efficient and capable of successfully handling large floor plans.’ (Ting-Chi Wang and D.F. Wong 1990, p. 180)The first step in designing a floor plan is to determine relative positions of the modules and use the interconnections among them. Costs measures are then minimized by performing various optimizations. Research that focused on efficient heuristic methods was done before the 1990’s. Horizontal and vertical line segments are used to divide in a certain amount of modules causing the same amount of non-overlapping rectangles. The following figure is a representation of an optimized floor plan:

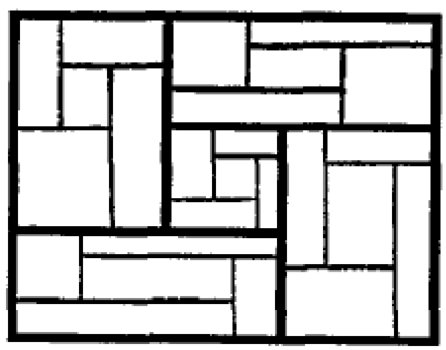


Figure 2: An optimized floor plan presented by Ting-Chi Wang and D.F. Wong (1990, p. 185) using the algorithm.

Chapter 2

5 Methods, Techniques and Tools for problem solving

5.1 Linear/Mathematical programming formulation

In the subject known as 'optimization' the most widely known, used and implemented technique for modeling and problem solving is 'Linear Programming'. Linear programming optimizes systems that may be modeled as a set of linear, mathematical functions (Ignizio 1982, preface). Mathematical programming is used to solve problems in areas such as operations research, decision analysis, economics, and management science. Typical problems such as the daily operations of a business or organization and the decisions that have to be made about costs and profits are typically addressed by mathematical programming. Most of the problems addressed by mathematical programming are sometimes too complicated to solve intuitively, and therefore computer algorithms are required. 'If all functions are linear, the problem is known as a linear programming problem.' (Van der Linden 2005, p. 333-334) Sometimes decisions have to be made under uncertainty. Hypotheses on the form of the probability distributions are necessary in these cases. These problems are solved using stochastic programming. 'Problems of stochastic programming have one or more random coefficients, and typically the objective is to optimize an expected value defined over these coefficients.' (Van der Linden 2005, p. 335-336)

5.2 Multiple objective linear programming

'Only one objective function can be optimized at a time. If we tried to optimize two functions simultaneously, each of them would draw the results into a different direction and a gain for the one would necessarily mean a loss for the other' (Van der Linden 2005, p. 40). It is possible to have more than one objective function. These problems are referred to as multi objective test assemblies. Several strategies exist for reformulating these functions. Examples of these are the optimization of a weighted average of the attributes, or the objectives can be prioritized and sequentially optimized (Van der Linden 2005, p. 40). A multiple objective model will be considered, because there will probably be multiple objectives that have to be addressed. These objectives are the maximization of profit while maximizing the amount of nutrients generated from the area of soil provided. The multi objective modelling is a highly flexible and practical methodology for modelling. This model has conflicting objectives; the one objective will always receive more benefit than the other. This can be used for modeling, solving and analyzing problems. More of the problems encountered in practice can be addressed. The baseline model can be converted into a multiple objective linear programming model. 'Happily we shall discover that the methodology of multiple objective linear programming is really no more difficult from that which was employed in the single-objective problem, and, in fact, there are even some simplifications to be gained.' (Van der Linden 2005, p. 372)

The following process of modeling a test-assembly was presented:

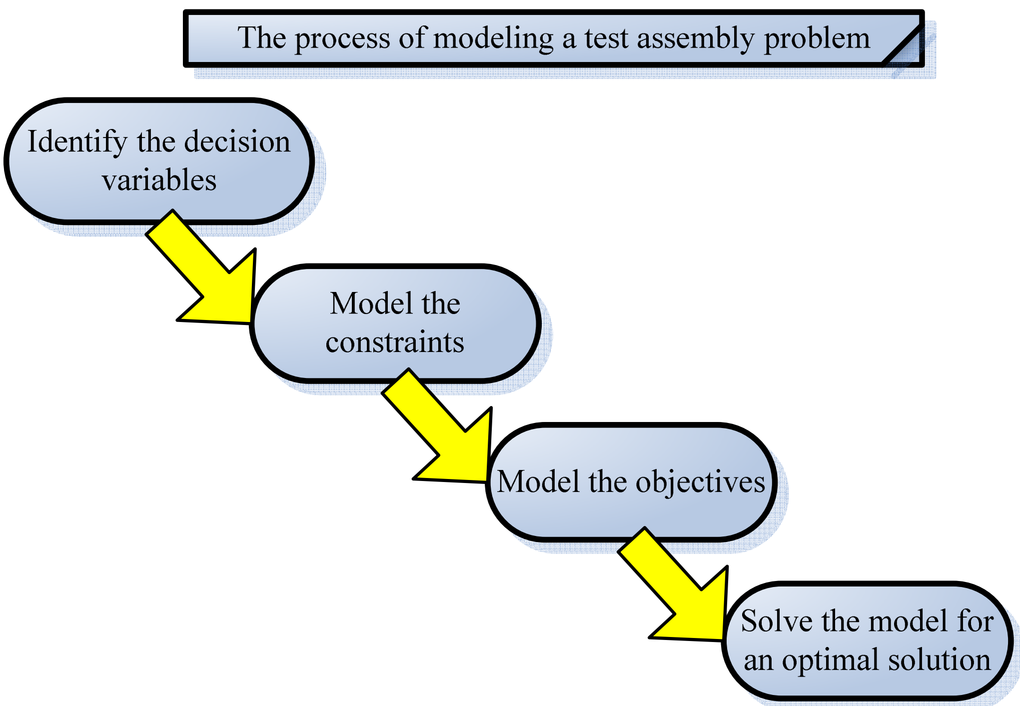


Figure 3: The process of modeling a test assembly as presented by Van der Linden (2005, p. 47)

5.3 Dynamic programming formulation

If the problem is time dependent, and one outcome depends on the outcome of a previous one, this problem belongs to the domain of dynamic programming or stochastic dynamic programming (Van der Linden 2005, p. 336).

‘It is quite possible that an agricultural or natural resource problem may need to be evaluated by more than one criterion. The criteria may be efficiency and equity, or private profit and pollution.’ (Kennedy 1986, p. 79)

‘Resource management problems are often problems of dynamic optimization. The dynamic optimization approach offers insight into the economics of dynamic optimization which can be explained much more simply than other approaches.’ (Kennedy 1986, preface) ‘Optimality conditions for the generalized problem are derived using the reasoning of dynamic programming.’ (Kennedy 1986, p. 5) ‘Whilst linear programming is computationally much more efficient than dynamic programming for solving deterministic problems with a linear objective function and linear constraints, dynamic programming may be more suitable for more intractable problems’ (Kennedy 1986, p. 6) One of the advantages of dynamic programming that only a few constraints are placed on functions. To solve problems using dynamic programming you need a certain structure. The following terms describe the required structure: decision, decision stage, state transformation function, stage return function and objective function. (Kennedy 1986, p. 31) ‘A major limitation of numerical dynamic programming is that because the number of possible ways of describing the state of a decision system increases exponentially with the number of state variable, problems with many state variables may impose excessive or infeasible computing and memory requirements.’ (Kennedy 1986, p. 79) There are some decisions that have to be made like the frequency and level of input applications, but besides these, some decisions on timing and density of planting have to be made as well. Often the final decisions are not solved by dynamic programming, because of large factors that play a role like the weather and the physiological characteristics of the plant. (Kennedy 1986, p. 160)

5.4 Critical path analysis

In most cases a large number of activities need to be carried out before a job can be completed. It may also be the case that one or more activities cannot start before one or more other activities have been completed. The critical path method is usually applied to determine the minimum time in which a project or schedule can be completed. In the case of this project it can be applied to determine the maximum profit that can be obtained from time zero to the end. (Kennedy 1986, pp. 129-130)

5.5 Stochastic Knapsack model

Another way of possibly solving this vegetable garden problem is to consider the so called Knapsack problem. Instead of items fitting into a knapsack, we will have certain amounts of vegetables that need to fit into a specific area of land. A system operates for a certain time period. Specific components are important and useful for certain time periods and then 'fails' or falls away, and must be replaced with new components. (Ross 1983, p. 122)

6 Basic formulation

Normal distributions will be used to determine the amount of nutrients in an average sized vegetable. Excel can be used for these types of calculations. The next step would be to construct a mathematical model with all of these averages as constants, with a certain amount of deviation, as well as a couple of variables.

Some or a combination of the models mentioned above will be considered to find a way of solving the vegetable garden problem. The mathematical model must be able to test all the possibilities necessary in order to get the most accurate optimal solution. At this stage it seems as if the answer would be a probability of probabilities. The right supporting tools and methods must be chosen in order to minimize the deviation, maximize the probability as well as the solution.

The following aspects will have to be used in the mathematical formulation:

- The different types of nutrients in the different vegetables
- The type of soil in which the vegetables are planted
- The type of fertilizer to be used
- The area of the garden
- Specific time of the year for specific types of vegetables
- Soil resting periods per type of vegetable
- A balance must be found between all of the nutrients
- A balanced diet must be followed
- A balance must be found between vegetables

A few financial aspects will have to be considered as well:

- The market buying price of each type of vegetable
- The profit of each type of vegetable after variable planting expenses
- The price of fertilizer
- The price of labour with regards to planting, harvesting, packaging and selling
- The price for extra water and primary needs
- The price of resources and implements
- All of the expenses to make the garden self sustainable
- Time value of money

7 Research Design

The main objective will be to find a solution that can tell you on a monthly basis exactly what type of vegetable to plant. There may be various ways of formulating this specific model. At this stage it seems as if an Excel formulation needs to be developed in order to find the amount of nutrient per area each vegetable provides and takes up. The probability of how each type of vegetable reacts in all of the different seasons will have to be part of this calculation in this Excel formulation. The next step is to formulate a mathematical model by using one or a combination of the following; linear programming, multiple-objective programming, dynamic programming, the critical path method or something similar to the knapsack model. The following procedure needs to be followed:

Formulation chapter flow diagram

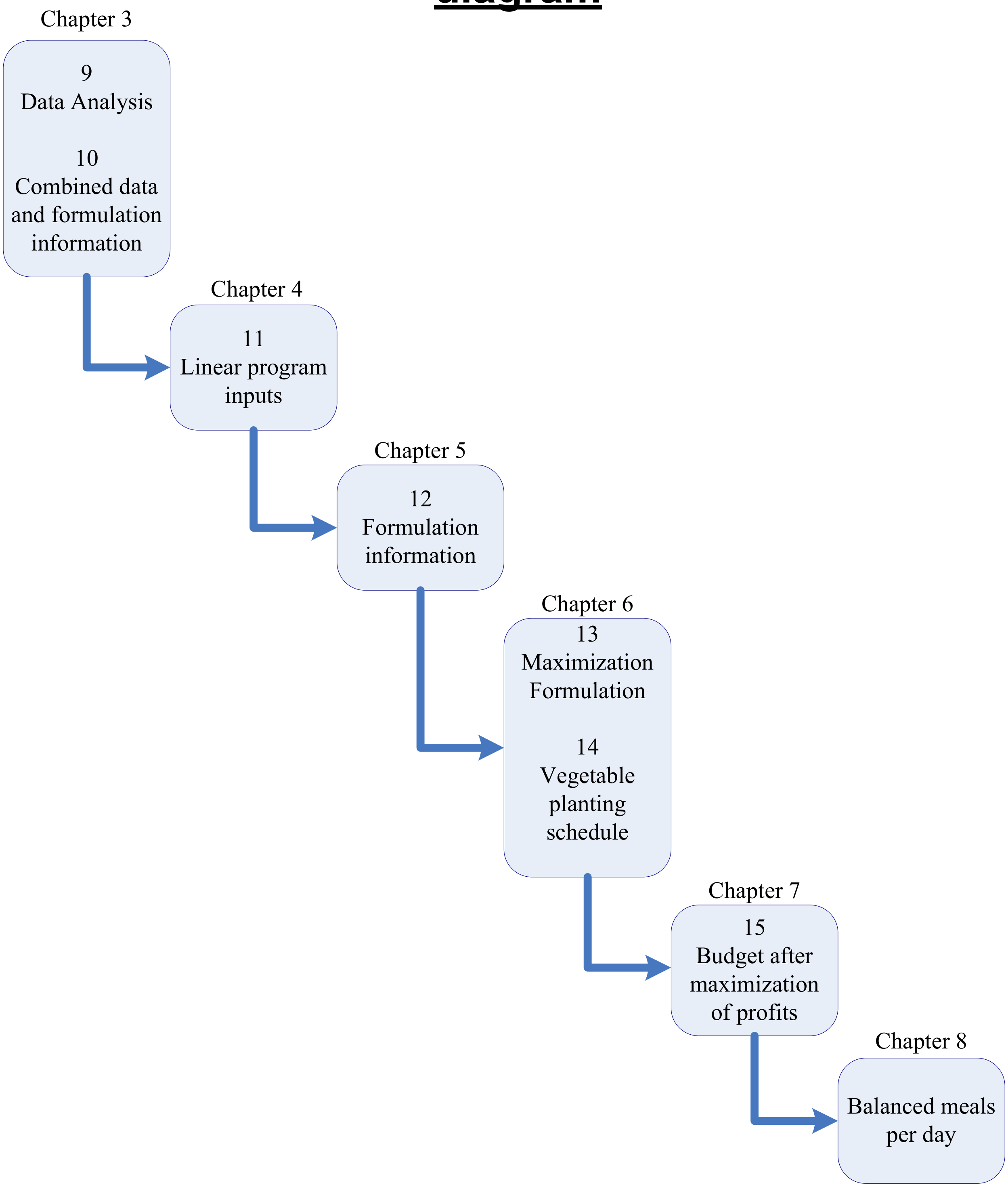


Figure 4: Chapter flow diagram

8 Research Methodology

The four steps required to successfully complete this project are discussed here.

8.1 Formulation

The aim is to maximize the total profit given the type of soil and the area you have to produce certain vegetables. The type of fertilizer, water usage, capacity, time of year, resting periods and all aspects mentioned under basic formulation need to be taken into account. The amount of money that would be spent on maintaining the garden must also be taken into account.

The period of the formulation is one year. The answer will have to be in terms of weeks to find a detailed schedule that continuously guides planting and harvesting activities. Information concerning the variables and constraints must be gathered, and fitted into the formulation. Maximizing the number of nutrients in the formulation will mean:

1. Producing enough food to satisfy 4500 OVC's through providing balanced diets
2. A daily balanced diet
3. Generating enough funds to make the farms self sustainable
4. Creating jobs, through payment to the farms workers
5. Building and promoting communities
6. Educating people in agricultural
7. Making a positive contribution to the field of agriculture

8.2 Solution Algorithm

An algorithm must be created to satisfy all of the needs and constraints of the Heartbeat foundation. All of the variables have to be taken into consideration, and all of the values must be converted into amounts of nutrients, or to basic costs. A possible objective function will be to maximize the profit.

8.3 Appropriate method

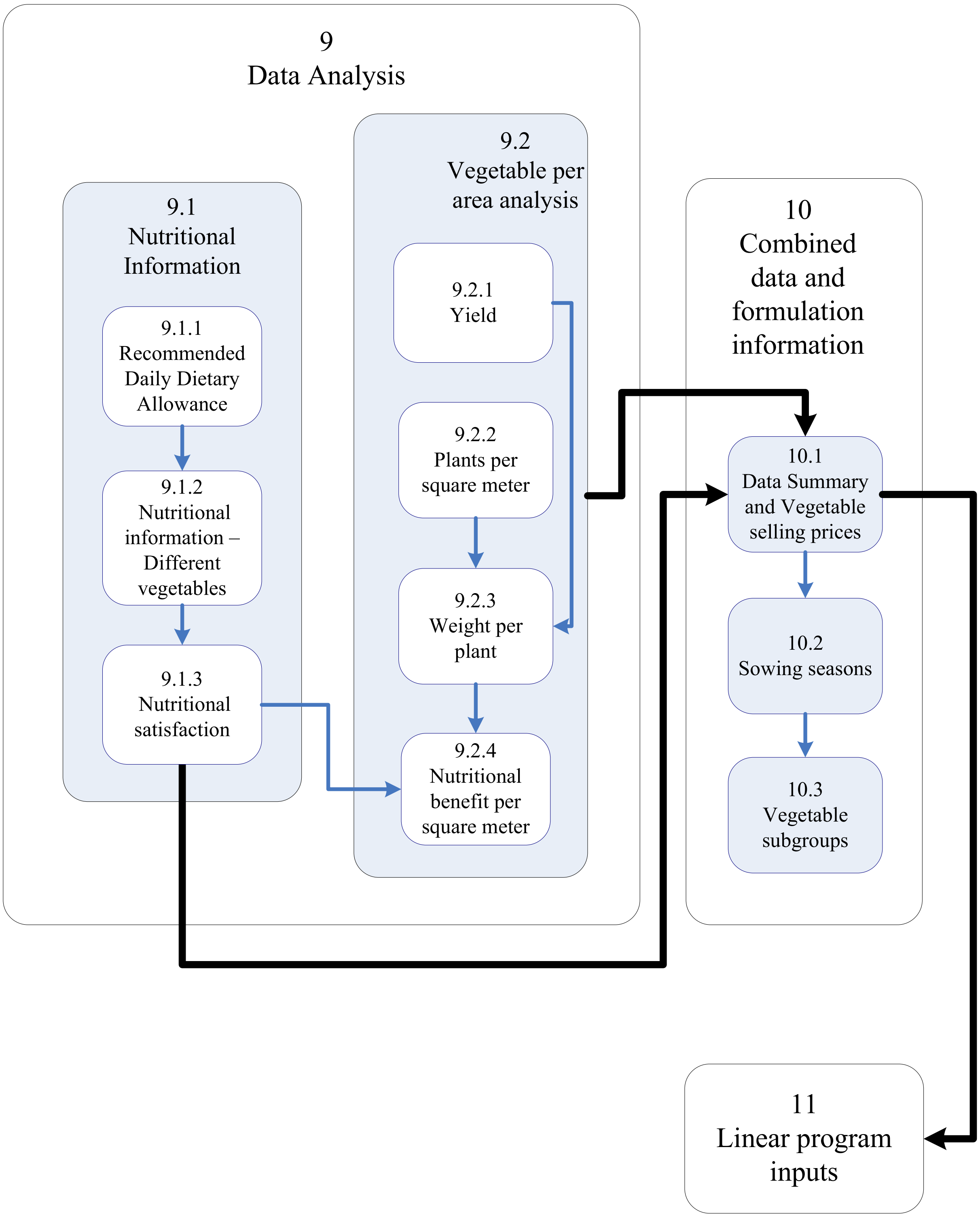
An appropriate method must be chosen, in order to get an optimal solution that can be used in practice. It must be determined whether the models will be stochastic or not. Some combination of the models mentioned earlier will probably be used to solve this problem

8.4 Test and Evaluate

After determining the appropriate methods and models, a solution algorithm must be created in order to solve the problem that was stated. After the solution is found, it must be tested and evaluated to determine if the need is fulfilled.

Chapter 3

Chapter 3 flow diagram



9 Data Analysis

9.1 Nutritional information

9.1.1 Recommended Daily Dietary Allowance

Different types of Minerals, Vitamins and Macronutrients are necessary each day for the human body to operate to its full potential. The human body needs these Minerals, Vitamins and Macronutrients in order to stay healthy and build up a strong immune system.

The Recommended Daily Dietary Allowance (RDA) of each nutrient has been determined through the use of several different sources. The following table provides information regarding the RDA of each individual Mineral, Vitamin and Macronutrient:

Recommended types of nutrients to be taken daily	100% Recommended daily dietary allowance in grams(On average between men and women) grams/day
Minerals	H25
Calcium	1
Iron (Fe)	0.018
Magnesium (Mg)	0.355
Phosphorus	0.7
Potassium (K)	4.7
Sodium	1.5
Zinc (Zn)	0.0095
Vitamins	
Vitamin C/Ascorbic Acid	0.0825
Thiamin/Vitamin B1	0.00115
Riboflavin/Vitamin B2	0.0012
Niacin/Vitamin B3	0.015
Pantothenic Acid	0.005
Vitamin B6	0.0013
Vitamin B12	0.0000024
Folate/Folic acid	0.0004
Vitamin A (IU)/Retinol	0.0008
Vitamin E	0.015
Selenium	0.000055
Macronutrients	
Water	3000
Protein	56
Carbohydrates	130
Fiber	25
Total fat	65
Saturated fat	20
Cholesterol	0.2

Table 1: RDA for the Human body presented by Whitney E., Rolfes S.R. 2008 in *Understanding nutrition*, 11^{th} ed.

9.1.2 Nutritional information on different types of vegetables

Data was collected regarding the nutritional potential of several different vegetables. The data that was collected needed to be transformed in order to find the nutritional value in an average sized vegetable of a specific plant. (Average weight of each plant per square meter will be discussed at section 9.2.3) A few types of common vegetables were selected Theses vegetables are: Butternut, Sweet potatoes, Potatoes, Lettuce, Tomatoes, Onions, Cucumber, Carrots, Spinach, Broccoli, Beetroot, as well as a few others. The following table provides an illustration of how the amount of Minerals, Vitamins and Macronutrients in one plant of Butternut was determined:

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. in 132g (1cup) of Butternut (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2500g) plant of Butternut (in grams, raw or cooked in water)
Minerals	C25	*=C25/132*2500
Calcium	0.025	0.473484848
Iron (Fe)	0.00077	0.014583333
Magnesium (Mg)	0.012	0.227272727
Phosphorus	0.03828	0.725
Potassium (K)	0.176	3.333333333
Sodium	0.003	0.056818182
Zinc (Zn)	0.00016	0.003030303
Vitamins		
Vitamin C/Ascorbic Acid	0.005	0.09469697
Thiamin/Vitamin B1	0.00007	0.001325758
Riboflavin/Vitamin B2	0.00005	0.00094697
Niacin/Vitamin B3	0.00061	0.01155303
Pantothenic Acid	0.000226533	0.004290393
Vitamin B6	0.00009	0.001704545
Vitamin B12	0	0
Folate/Folic acid	0.000022	0.000416667
Vitamin A (IU)/Retinol	0	0
Vitamin E	0	0
Selenium	0.000006	0.000113636
Macronutrients		
Water	116	2196.969697
Protein	2	37.87878788
Carbohydrates	13	246.2121212
Fiber	2	37.87878788
Total fat	0.99	18.75
Saturated fat	0.02	0.378787879
Cholesterol	0.04	0.757575758

Table 2: Amount of nutrients in an average plant of Butternut

(NB! One plant of a certain vegetable is not necessarily one item of that specific vegetable)

9.1.3 Nutritional satisfaction each vegetable provides

Each vegetable can now be 'rated' according to the amount of nutrients it provides. If the amount of nutrients in each vegetable were to be compared to the amount a person needs per day, a balanced 'scale' can be developed in order to compare the importance of each vegetable. Some of the vegetables provide more Vitamins, Minerals and Macronutrients than are required for a healthy diet. This nutrient model is only a 'scale' to be able to compare the different types of vegetables against each other. If the individual amounts of nutrients provided by each different plant of vegetable were to be divided by the individual amounts RDA nutrients, a balance will be reached between each individual type of nutrient in each type of vegetable. Table 3 provides these amounts for Butternut:

recommended types of nutrients to be taken daily	`rating` of importance of butternut - Amount of nutritional satisfaction a plant of butternut provides given the importance of each nutrient	Percentage `rating` of importance of butternut - Amount of nutritional satisfaction a plant of butternut provides given the importance of each nutrient
Minerals	*K25=D25/H25	*K26=K25*100
Calcium	0.473484848	47.34848485
Iron (Fe)	0.810185185	81.01851852
Magnesium (Mg)	0.640204866	64.02048656
Phosphorus	1.035714286	103.5714286
Potassium (K)	0.709219858	70.92198582
Sodium	0.037878788	3.787878788
Zinc (Zn)	0.318979266	31.89792663
Vitamins		
Vitamin C/Ascorbic Acid	1.147842057	114.7842057
Thiamin/Vitamin B1	1.152832675	115.2832675
Riboflavin/Vitamin B2	0.789141414	78.91414141
Niacin/Vitamin B3	0.77020202	77.02020202
Pantothenic Acid	0.858078603	85.80786026
Vitamin B6	1.311188811	131.1188811
Vitamin B12	0	0
Folate/Folic acid	1.041666667	104.1666667
Vitamin A (IU)/Retinol	0	0
Vitamin E	0	0
Selenium	2.066115702	206.6115702
Macronutrients		
Water	0.732323232	73.23232323
Protein	0.676406926	67.64069264
Carbohydrates	1.893939394	189.3939394
Fiber	1.515151515	151.5151515
Total fat	0.288461538	28.84615385
Saturated fat	0.018939394	1.893939394
Cholesterol	3.787878788	378.7878788
	average	88.30334334
	total	2207.583583

Table 3: Importance rating of different vegetables

9.2 Vegetable per area analysis

9.2.1 Yield

The amount of kilograms per square meter one can harvest of each vegetable will differ between vegetables, rainfall regions, type of soil, preparation of soil and different types of fertilizer used. The yield of each vegetable in each region was determined by Hygrotech. Hygrotech consist of several companies across South Africa. Their latest research have shown the amount of tons per hectare each region in South Africa will deliver, and at which time of year each vegetable can be planted. In this case we consider the Highveld region in the Gauteng area. These amounts make provision for the fact that there must be some space in the form of passages between the plants. For the scope of this project the assumption will be made that the right preparation, fertilizer and amount of water is available to create ideal growing conditions. A few calculations were done with these researched values, in order to determine the amount of nutrients each square meter of different vegetable will be available. The calculations for Butternut were done as follow:

Average yield of butternut per hectare (ton/ha.)	25

This 'Average yield of butternut per hectare' value was multiplied by 1000 to determine the amount of kilograms per hectare, and then divided by 10000 (number of square meters in 1 hectare) to determine the amount of kilograms per square meter:

Average yield of butternut per square meter (kg/m^2)	2.5

9.2.2 Amount of plants per square meter

Hygrotech also determined the average amount of plants in each hectare. By dividing the average amount of plants in each hectare by 10000 the average amount of plants in each square meter can be determined.

Amount of square meters in 1 Hectare	10000
Average amount of plants per square meter	1
Average amount of plants per hectare	10000

9.2.3 Weight per plant

The average weight of 1 plant of butternut can now be determined by dividing the 'Average yield of butternut per square meter' by the 'Average amount of plants per square meter'. This simple calculation can be done to determine the weight of each plant on average. All of nutritional information was converted to grams, so the average weight of the plant needed to be measured in grams. The following is an example:

Average weight of 1 plant of butternut (kilogram)	2.5
Average weight of 1 plant of butternut (gram)	2500

NB! These values were used to convert the amount of Minerals, Vitamins and Macronutrients in each vegetable from a cup, or half a cup sized amount, to a whole plant sized amount.
(As can be seen in section 9.1.2).

9.2.4 Nutritional benefit per square meter

The average and total nutritional benefit per square meter can now be determined. The total and average nutritional satisfaction each plant of specific vegetable provides (as determined in section 9.1.3) can be multiplied by the 'Average amount of plants per square meter', and will result in the 'Amount of nutritional benefit a square meter of butternut will deliver'. The total or average amount can be used, and will be discussed later on in this chapter. The following nutritional amounts were determined for a square meter of butternut:

Amount of nutritional benefit a square meter of butternut will deliver	total	2207.583583
	average	88.30334334

10 Combined data and formulation information

10.1 Data summary

All of the nutritional values of all the different vegetables were summarized. The average and total nutrient values were summarized, and multiplied by the ‘Average amount of plants per square meter’. The average and total nutrient value per square meter were calculated. A market price that can be earned from selling each type of vegetable per kilogram was determined. The market buying price per kilogram was multiplied by the ‘Average yield per square meter’. By using this calculation the average market buying price per square meter was calculated for each individual type of vegetable.

The following is a summary of the nutrient values of vegetables per square meter:

Summary of nutrient value of vegetables per square meter					
	Nutrient value per plant			Nutrient value per square meter	
Vegetable	Average	Total	Average amount of plants per square meter	Average	Total
Butternut	88.30334334	2207.583583	1	88.30334334	**2207.58**
Sweet potatoes	235.6125675	5890.314188	10	2356.125675	**58903.14**
Potatoes	57.0131999	1425.329997	10	570.131999	**14253.30**
Lettuce	16.86970188	404.8728452	7.75	130.7401896	**3137.76**
Tomatoes	77.8780952	1869.074285	3.1	241.4220951	**5794.13**
Onions	21.64557558	541.1393894	6.5	140.6962413	**3517.41**
Cucumber	360.6420595	9016.051489	1.15	414.7383685	**10368.46**
Carrots	1.407203853	35.18009634	200	281.4407707	**7036.02**
Spinach	8.825646726	220.6411681	24.5	216.2283448	**5405.71**
Broccoli	71.56863138	1789.215785	3	214.7058941	**5367.65**
Beet	5.188930072	129.7232518	26	134.9121819	**3372.80**
Cabbage	119.6811132	2992.02783	3.5	418.8838961	**10472.10**
Garden Peas	2.118048894	52.95122234	13	27.53463562	**688.37**
Peppers	55.97788807	1399.447202	3.75	209.9170803	**5247.93**
Pumpkin	132.4653499	3311.633747	0.85	112.5955474	**2814.89**
Squash	98.00071922	2450.01798	1.35	132.3009709	**3307.52**
Radish	0.645612704	16.14031759	100	64.56127036	**1614.03**
Corn	20.50134	512.5335001	7	143.50938	**3587.73**
Turnips	4.045165241	101.129131	30	121.3549572	**3033.87**

Table 4: Summary of nutrient values and market buying prices

The following is a summary of the vegetable selling prices per kilogram, as well as per square meter:

Summary of vegetable selling prices per square meter			
	Market buying price as on 23 Sept 2009 at 13H00		Market buying price
Vegetable	Per kilogram	Average Yield per square meter (kg/sqm)	Per square meter
Butternut	R 2.31	2.5	**R 5.78**
Sweet potatoes	R 1.40	21.3	**R 29.82**
Potatoes	R 4.79	10	**R 47.90**
Lettuce	R 1.73	7.75	**R 13.41**
Tomatoes	R 4.65	3.1	**R 14.42**
Onions	R 3.03	5	**R 15.15**
Cucumber	R 5.11	1.15	**R 5.88**
Carrots	R 2.24	3.75	**R 8.40**
Spinach	R 3.50	1.75	**R 6.13**
Broccoli	R 1.25	1.15	**R 1.44**
Beet	R 2.39	3.25	**R 7.77**
Cabbage	R 1.17	7	**R 8.19**
Garden Peas	R 9.83	0.4	**R 3.93**
Peppers	R 5.33	3	**R 15.99**
Pumpkin	R 1.13	2.5	**R 2.83**
Squash	R 2.30	2.25	**R 5.18**
Radish	R 8.48	1	**R 8.48**
Corn	R 1.75	2.25	**R 3.94**
Turnips	R 3.04	3.25	**R 9.88**

Table 5: Summary of vegetable selling prices per square meter

10.2 Sowing seasons

Certain regions can accommodate certain types of vegetables. Some of the factors contributing to the region-vegetable combination are the average amount of rainfall per year in the region, the type of soil, the climate and humidity. Certain types of vegetables can only be planted at a certain time in the year in a specific region. If the different vegetables are planted in the correct month it is assumed to reach full potential if the conditions as mentioned in section 9.2.1 are ideal. The following list provides information on the types of vegetables and the month in which it can be planted in the Gauteng area or Highveld:

- Butternut - Aug, Sept, Oct, Nov
- Sweet potatoes - Jul, Aug
- Potatoes - Jan, Feb, Mar, Sept, Oct
- Lettuce - Jan, Feb, Mar, May, Jun, Jul, Aug, Sept
- Tomatoes - Feb, Mar, May, Aug, Sept, Oct, Nov, Dec
- Onions - Feb, Mar, May,
- Cucumber - Sept, Oct, Nov, Des
- Carrots - Jan, Feb, Mar, Jun, Jul, Aug, Sept, Oct
- Spinach - Jan, Feb, Mar, Apr, Aug, Sept, Oct, Nov, Dec
- Broccoli - Jan, Feb, Sept, Oct, Nov, Dec
- Beet - Jan, Feb, Mar, Jun, Jul, Aug, Sept, Oct
- Cabbage - Jan, Feb, Sept, Nov, Des
- Garden Peas - Jul, Aug, Sept
- Peppers - Aug, Sept, Oct
- Pumpkin - Sept, Oct, Nov
- Squash - Aug, Sept, Oct, Nov
- Radish - Jan, Feb, Mar, Apr, Jun, Aug, Sept, Oct, Nov
- Corn - Aug, Sept, Oct, Nov
- Turnips - Jan, Feb, Mar, Apr, Jun, Jul, Aug, Sept

The following schedule was constructed in order to show the nutritional value that each square meter of the different vegetables will deliver when harvested, given the month in which it is planted:

	Expected nutrient values per square meter (when harvested) given planted each month																	
	2009			**2010**												**2011**		
Vegetable	**Oct**	**Nov**	**Des**	**Jan.**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan.**	**Feb**	**Mar**
Butternut	2207.58	2207.58	0	0	0	0	0	0	0	0	2207.58	2207.58	2207.58	2207.58	0	0	0	0
Sweet potatoes	0	0	0	0	0	0	0	0	0	58903.14	58903.14	0	0	0	0	0	0	0
Potatoes	14253.30	0	0	14253.30	14253.30	14253.30	0	0	0	0	0	14253.30	14253.30	0	0	14253.30	14253.30	14253.30
Lettuce	0.00	0	0	3137.76	3137.76	3137.76	0	3137.76	3137.76	3137.76	3137.76	3137.76	0	0	0	3137.76	3137.76	3137.76
Tomatoes	5794.13	5794.13	5794.13	0	5794.13	5794.13	0	5794.13	0	0	5794.13	5794.13	5794.13	5794.13	5794.13	0	5794.13	5794.13
Onions	0	0	0	0	3517.41	3517.41	0	3517.41	0	0	0	0	0	0	0	0	3517.41	3517.41
Cucumber	#####	10368.46	10368.46	0	0	0	0	0	0	0	0	10368.46	10368.46	10368.46	10368.46	0	0	0
Carrots	7036.02	0	0	7036.02	7036.02	7036.02	0	0	7036.02	7036.02	7036.02	7036.02	7036.02	0	0	7036.02	7036.02	7036.02
Spinach	5405.71	5405.71	5405.71	5405.71	5405.71	5405.71	5405.71	0	0	0	5405.71	5405.71	5405.71	5405.71	5405.71	5405.71	5405.71	5405.71
Broccoli	5367.65	5367.65	5367.65	5367.65	5367.65	0	0	0	0	0	0	5367.65	5367.65	5367.65	5367.65	5367.65	5367.65	0
Beet	3372.80	0	0	3372.80	3372.80	3372.80	0	0	3372.80	3372.80	3372.80	3372.80	3372.80	0	0	3372.80	3372.80	3372.80
Cabbage	0	10472.10	10472.10	10472.10	10472.10	0	0	0	0	0	0	10472.10	0	10472.10	10472.10	10472.10	10472.10	0
Garden Peas	0	0	0	0	0	0	0	0	0	688.37	688.37	688.37	0	0	0	0	0	0
Peppers	5247.93	0	0	0	0	0	0	0	0	0	5247.93	5247.93	5247.93	0	0	0	0	0
Pumpkin	2814.89	2814.89	0	0	0	0	0	0	0	0	0	2814.89	2814.89	2814.89	0	0	0	0
Squash	3307.52	3307.52	0	0	0	0	0	0	0	0	3307.52	3307.52	3307.52	3307.52	0	0	0	0
Radish	1614.03	1614.03	0	1614.03	1614.03	1614.03	1614.03	0	1614.03	0	1614.03	1614.03	1614.03	1614.03	0	1614.03	1614.03	1614.03
Corn	3587.73	3587.73	0	0	0	0	0	0	0	0	3587.73	3587.73	3587.73	3587.73	0	0	0	0
Turnips	0	0	0	3033.87	3033.87	3033.87	3033.87	0	3033.87	3033.87	3033.87	3033.87	0	0	0	3033.87	3033.87	3033.87

Table 6: Expected nutrient values given planted each month

10.3 Vegetable subgroups

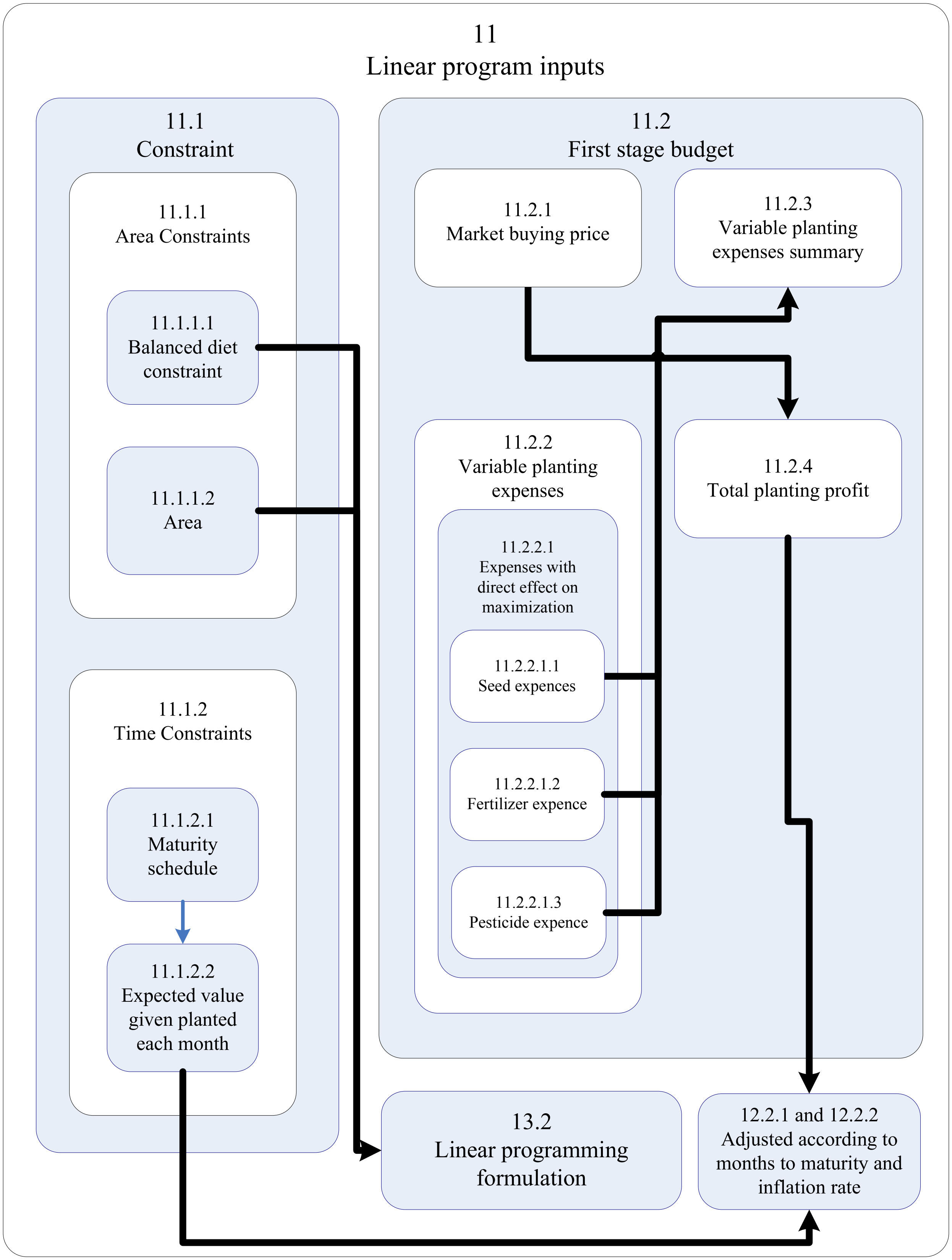
Three main vegetable subgroups were identified that needed to be taken weekly according to Understanding Nutrition p.41 by E. Whitney and S.R. Rolfes. These three subgroups are dark green vegetables, red, orange and dark yellow vegetables and starchy vegetables.

The following list shows the different vegetables, and the subgroups to which they belong:

- Dark Green
    - Lettuce
    - Onions
    - Cucumber
    - Spinach
    - Broccoli
    - Garden peas
    - Cabbage
- Red, Orange, Dark Yellow
    - Tomatoes
    - Carrots
    - Peppers
    - Squash
    - Beet
- Starchy
    - Butternut
    - Sweet potatoes
    - Potatoes
    - Corn
    - Turnips
    - Pumpkin

Chapter 4

Chapter 4 flow diagram



11 Linear program inputs

11.1 Constraints

11.1.1 Area Constraints

Two constraints were identified; the balanced diet constraint and the area constraint. The 'Expected values given planted each month' will also count as a constraint, as only a selected few can be chosen each month. This will be discussed in section 11.1.2.2.

11.1.1.1 Balanced diet constraint

One of the main reasons for this project is to be able to create a solution that will ensure that the people in Nellmapius will follow a healthy and balanced diet. Research has shown a dietary balance between these subgroups. Table 7 shows the amount (in cups) of vegetable subgroups that needed to be taken weekly, to create a healthy diet for persons with different energy (calorie) level needs per day. The average intake per vegetable subgroup was determined, and all of the averages added up. Table 7 shows these amounts:

Recommended weekly amounts of vegetable intake									
kcal(usage per dag)	1600	1800	2000	2200	2400	2600	2800	3000	average
Dark green (cups)	2	3	3	3	3	3	3	3	2.875
Red, Orange and dark yellow (cups)	1.5	2	2	2	2	2.5	2.5	2.5	2.125
Starch (cups)	2.5	3	3	6	6	7	7	9	5.4375
								total	10.4375

Table 7: Recommended weekly amount of vegetable intake from different vegetable subgroups

Using the information in table 7, a balance can be determined between all of the different subgroups. Table 8 shows the percentage of each vegetable subgroup that needs to be taken daily or weekly. The percentages were determined, by dividing the average amount of cups per person per week for each subgroup, by the total average amount of cups of vegetables needed per week.

Vegetable subgroups	**Percentage ratio between vegetable subgroups**
Dark green	27.54%
Red, Orange and dark yellow	20.36%
Starch	52.10%

Table 8: Percentage ratio to be taken daily

This information can now be used as an additional constraint on the area. If the area is in balance according to the vegetable subgroups, a balance will be reached for feeding people on a monthly basis. A balanced meal must have 27.54% dark green vegetables, 20.36% red, orange and dark yellow vegetables and 52.10% starch. The area need to be divided into these percentages in order to create a huge balanced meal, that can be divided between people.

11.1.1.2 Area

In order to create a constraint on the given area, a 'Relative square meter area ratio' needs to be placed on each vegetable. The more nutrients a certain vegetable provides, the more beneficial it will be if it is selected, and visa versa. The following 'Relative square meter area ratio's were determined according to the vegetable with the highest nutrients per square meter value. In this case Sweet potatoes were selected. Sweet potatoes have a nutrient value per square meter of 58903.14, which is the highest. All of the other vegetables' nutritional values were compared to the nutritional value of Sweet potatoes. In other words, the amount of nutrients in 1 square meter of Sweet potatoes will be equal to 27 square meter of Butternut. Table 7 provides the relative square meter ratios of all the different vegetables:

Vegetable	Relative square meter 'area' ratio - Total
Dark Green	
Lettuce	**19**
Onions	**17**
Cucumber	**6**
Spinach	**11**
Broccoli	**11**
Garden peas	**86**
Cabbage	**6**
Red, Orange, Dark Yellow	
Tomatoes	**10**
Carrots	**8**
Peppers	**11**
Squash	**18**
Radish	**36**
Beet	**17**
Starchy	
Butternut	**27**
Sweet potatoes	**1**
Potatoes	**4**
Corn	**16**
Turnips	**19**
Pumpkin	**21**

Table 9: Relative square meter area ratio

The market buying price for each vegetable also needs to be adjusted according to the 'Relative square meter area ratio'. This will be discussed in section 11.2

11.1.2 Time constraints

11.1.2.1 Maturity schedule

Another constraint that needs to be part of the formulation is the time each type of vegetable needs to reach maturity. The people need to be fed each month, vegetables in each different subgroup need to ripen each month in accordance with the vegetable subgroup percentages.

11.1.2.2 Expected value given planted each month

All of the values given in section 11.1.1.1 and section 11.2.1(which will be discussed shortly) are reliant on the fact that only certain vegetables can be planted in certain months of the year. This will result in the following table which will be used as two of the constraints:

Vegetable subgroups

	Relative square meter 'area' ratio given planted each month																	
Vegetable	**2009**			**2010**												**2011**		
Dark Green	**Oct**	**Nov**	**Dec**	**Jan.**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Lettuce	0	0	0	19	19	19	0	19	19	19	19	19	0	0	0	19	19	19
Onions	0	0	0	0	17	17	0	17	0	0	0	0	0	0	0	0	17	17
Cucumber	6	6	6	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0
Spinach	11	11	11	11	11	11	11	0	0	0	11	11	11	11	11	11	11	11
Broccoli	11	11	11	11	11	0	0	0	0	0	0	11	11	11	11	11	11	0
Garden peas	0	0	0	0	0	0	0	0	0	86	86	86	0	0	0	0	0	0
Cabbage	0	6	6	6	6	0	0	0	0	0	0	6	0	6	6	6	6	0
Red, Orange, Dark Yellow																		
Tomatoes	10	10	10	0	10	10	0	10	0	0	10	10	10	10	10	0	10	10
Carrots	8	0	0	8	8	8	0	0	8	8	8	8	8	0	0	8	8	8
Peppers	11	0	0	0	0	0	0	0	0	0	11	11	11	0	0	0	0	0
Squash	18	18	0	0	0	0	0	0	0	0	18	18	18	18	0	0	0	0
Radish	36	36	0	36	36	36	36	0	36	0	36	36	36	36	0	36	36	36
Beets	17	0	0	17	17	17	0	0	17	17	17	17	17	0	0	17	17	17
Starchy																		
Butternut	27	27	0	0	0	0	0	0	0	0	27	27	27	27	0	0	0	0
Sweet potatoes	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Potatoes	4	0	0	4	4	4	0	0	0	0	0	4	4	0	0	4	4	4
Corn	16	16	0	0	0	0	0	0	0	0	16	16	16	16	0	0	0	0
Turnips	0	0	0	19	19	19	19	0	19	19	19	19	0	0	0	19	19	19
Pumpkin	21	21	0	0	0	0	0	0	0	0	0	21	21	21	0	0	0	0

Table 10: Relative square meter area ratio given planted each month

11.2 First stage budget

11.2.1 Market buying price

The market buying price needed to be adjusted according to the 'Relative square meter area ratio'. This needed to be done to be able to use to market buying price in the maximization formulation. The original market buying price per square meter can be multiplied by the square meter area ratio as mentioned above. The following table provides all of the market buying prices (or the sales income we as producer will gain) as on the 23rd of September at the Johannesburg Fresh Produce Market (JFPM) per relative square meter area:

Vegetable	Market buying price (benefit) per Relative square meter
Dark Green	
Lettuce	**R 254.74**
Onions	**R 257.55**
Cucumber	**R 35.26**
Spinach	**R 67.38**
Broccoli	**R 15.81**
Garden peas	**R 338.15**
Cabbage	**R 49.14**
Red, Orange, Dark Yellow	
Tomatoes	**R 144.15**
Carrots	**R 67.20**
Peppers	**R 175.89**
Squash	**R 49.86**
Radish	**R 305.28**
Beet	**R 132.05**
Starchy	
Butternut	**R 155.93**
Sweet potatoes	**R 29.82**
Potatoes	**R 191.60**
Corn	**R 63.00**
Turnips	**R 187.72**
Pumpkin	**R 59.33**

Table 11: Amount of sales income per square meter for each vegetable

The market buying price will depend on inflation, and the month in which it is planted.[1] Sometimes, when a farmer plants his crops, a market price per ton will be determined and made official before harvesting. Table 12 is a representation of how inflation will play a role on a monthly basis. This is important when deciding to sell some of the harvested crops in order to generate funds for self sustainability.

[1] NB! The prices used in this document aren't necessarily a true reflection of actual prices in industry. The reason for that is the fact that vegetable prices depend on the amount of demand at a specific date. The demand differs with time, and trends for these type of demands can only be determined by specialists in the field. Expected values can only be determined, and isn't always accurate. For the purpose of this project an expected market buying price was determined. An inflation rate of 10% per year was used, and prices determined for the period October 2009 to March 2011.

Vegetable	Starting price	Gross margin before constant expenses (benefit, given planted each month) per Relative square meter given price inflation of 10% per year																			
		2009			2010													2011			
		Oct	Nov	Dec	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Dark Green																			
Lettuce	**R 254.74**	-	-	-	R257.93	R 258.99	R 260.05	-	R 262.17	R 263.23	R 264.30	R 265.36	R 266.42	-	-	-	R 270.66	R 271.73	R 272.79
Onions	**R 257.55**	-	-	-	-	R 261.84	R 262.92	-	R 265.06	-	-	-	-	-	-	-	-	R 274.72	R 275.79
Cucumber	**R 35.26**	R 35.26	R 35.41	R 35.55	-	-	-	-	-	-	-	-	R 36.88	R 37.02	R 37.17	R 37.32	-	-	-
Spinach	**R 67.38**	R 67.38	R 67.66	R 67.94	R 68.22	R 68.50	R 68.78	R 69.06	-	-	-	R 70.18	R 70.46	R 70.74	R 71.02	R 71.31	R 71.59	R 71.87	R 72.15
Broccoli	**R 15.81**	R 15.81	R 15.88	R 16.08	R 16.01	R 16.08	R 0.00	R 0.00	-	-	-	-	R 16.54	R 16.60	R 16.67	R 16.73	R 16.80	R 16.87	-
Garden peas	**R 338.15**	-	-	-	-	-	-	-	-	-	R 350.83	R 352.24	R 353.65	-	-	-	-	-	-
Cabbage	**R 49.14**	-	R 49.34	R 49.55	R 49.75	R 49.96	-	-	-	-	-	-	R 51.39	-	R 51.80	R 52.01	R 52.21	R 52.42	-
Red, Orange, Dark Yellow																			
Tomatoes	**R 144.15**	R 144.15	R 144.75	R 145.35	-	R 146.55	R 147.15	-	R 148.35	-	-	R 150.16	R 150.76	R 151.36	R 151.96	R 152.56	-	R 153.76	R 154.36
Carrots	**R 67.20**	R 67.20	-	-	R 68.04	R 68.32	R 68.60	-	-	R 69.44	R 69.72	R 70.00	R 73.47	R 70.56	-	-	R 71.40	R 71.68	R 71.96
Peppers	**R 175.89**	R 175.89	R 0.00	-	-	-	-	-	-	-	-	R 183.22	R 183.95	R 184.68	-	-	-	-	-
Squash	**R 49.86**	R 49.86	R 50.07	-	-	-	-	-	-	-	-	R 51.94	R 52.15	R 52.35	R 52.56	-	-	-	-
Radish	**R 305.28**	R 305.28	R 306.55	-	R 3	R 310.37	R 311.64	R 312.91	-	R 315.46	-	R 318.00	R 319.27	R 320.54	R 321.82	-	R 324.36	R 325.63	R 326.90
Beet	**R 132.05**	R 132.05	-	-	R 133.70	R 134.25	R 134.80	-	-	R 136.45	R 137.00	R 137.55	R 138.10	R 138.65	-	-	R 140.30	R 140.85	R 141.40
Starchy																			
Butternut	**R 155.93**	R 155.93	R 156.57	-	-	-	-	-	-	-	-	R 162.42	R 163.07	R 163.72	R 164.37	-	-	-	-
Sweet potatoes	**R 29.82**	-	-	-	-	-	-	-	-	-	R 30.94	R 31.06	-	-	-	-	-	-	-
Potatoes	**R 191.60**	R 191.60	-	-		R 194.79	R 195.59	-	-	-	-	-	R 200.38	R 201.18	-	-	R 203.58	R 204.37	R 205.17
Corn	**R 63.00**	R 63.00	R 63.26	-	-	-	-	-	-	-	-	R 65.63	R 65.89	R 66.15	R 66.41	-	-	-	-
Turnips	**R 187.72**	-	-	-	R 190.07	R 190.85	R 191.63	R 192.41	-	R 193.98	R 194.76	R 195.54	R 196.32	-	-	-	R 199.45	R 200.23	R 201.02
Pumpkin	**R 59.33**	R 59.33	R 59.57	-	-	-	-	-	-	-	-	-	R 62.04	R 62.29	R 62.54	-	-	-	-

Table 12: Effect of price inflation on market buying price given planted each month before variable expenses

11.2.2 Variable planting expenses

11.2.2.1 Expenses with direct effect on maximization

Variable expenses need to be deducted from the objective function. Some of the variable expenses will be the amount of seed, fertilizer, extra water supply and soil preparation needed, to create ideal growing conditions. These expenses will form part of the recursion, and be deducted from expected profits if all of the crops were to be sold. Expenses such as constant expenses and variable selling expenses will be deducted after the maximum profits are determined. The reason for this is because the variable planting expenses need to be deducted before the vegetables are planted. The amount of variable selling expenses can only be determined after the amounts of vegetables available are known.

There are a few expenses that will have a direct effect on the vegetables to be planed. The farm will be labour intensive. No tractors or special equipment will be used. The expenses that will be relevant will be the price of seed, fertilizer, pesticides and water. The assumption will be made that the water supply will be sufficient, so the expense of water isn't included. The following 3 sections will provide information on the amount of variable planting expenses.

11.2.2.1.1 Seed expenses

Generally the price for vegetable seeds is revised each month. The latest price for seed per kilogram I found was for July 2009. All of the seed prices obtained are for open pollinated seed, and sufficient for small scale farming which is perfect for the use at Nellmapius. This information was obtained from Hygrotechs' Ghian du Toit on 7 October 2009 who is a specialist in the field of vegetable seed and did his Masters degree in Agricultural Economics at the University of Pretoria. Seeds aren't always sold in price per kilogram. Some of the seeds are sold in price per amount of seeds, or more than 1 kilogram. All of these prices were converted to price per kilogram

The following table provides the prices of seed per relative square meter area ratio. The price per hectare was determined by multiplying the obtained value of seed per kilogram with the amount of seed needed per hectare. The amount of seed needed per square meter can be determined, and multiplied by the ‘relative square meter area ratio’ to determine the ‘Price of seed per relative square meter area ratio’, in order to keep the whole formulation in balance. Table 13 provides these values:

Price of seed per relative square meter area ratio						
Vegetable	**Price for seed per kilogram as in July 2009**	**Seed needed per hectare (kg/ha.)**	**Price per hectare**	**Price per square meter**	**Relative square meter area ratio**	**Price per relative square meter area ratio**
Dark Green						
Lettuce	R 1,132.60	1.05	R 1,189.23	R 1.19	19	R 22.60
Onions	R 260.70	4.25	R 1,107.98	R 1.11	17	R 18.84
Cucumber	R 493.10	3.00	R 1,479.30	R 1.48	6	R 8.88
Spinach	R 181.70	17.50	R 3,179.75	R 3.18	11	R 34.98
Broccoli	R 2,664.75	0.40	R 1,065.90	R 1.07	4	R 4.26
Garden peas	R 30.70	110.00	R 3,377.00	R 3.38	86	R 290.42
Cabbage	R 224.30	1.25	R 280.38	R 0.28	6	R 1.68
Red, Orange, Dark Yellow						
Tomatoes	R 8,169.00	0.30	R 2,450.70	R 2.45	10	R 24.51
Carrots	R 396.50	2.75	R 1,090.38	R 1.09	8	R 8.72
Peppers	R 1,554.60	2.00	R 3,109.20	R 3.11	11	R 34.20
Squash	R 132.50	1.75	R 231.88	R 0.23	18	R 4.17
Radish	R 163.30	11.00	R 1,796.30	R 1.80	36	R 64.67
Beet	R 83.10	6.00	R 498.60	R 0.50	17	R 8.48
Starchy						
Butternut	R 265.50	1.75	R 464.63	R 0.46	27	R 12.54
Sweet potatoes	R 0.30	7.00	-	R 2.10	1	R 2.10
Potatoes	R 0.20	7.00	-	R 1.40	4	R 5.60
Corn	R 10.50	17.50	R 183.75	R 0.18	16	R 2.94
Turnips	R 117.30	2.50	R 293.25	R 0.29	19	R 5.57
Pumpkin	R 132.50	1.75	R 231.88	R 0.23	21	R 4.87

Table 13: Price of seed per relative square meter area ratio

11.2.2.1.2 Fertilizer expenses

Each type of vegetable extracts an unique amount of nutrients out of the soil, that needs to be replaced after harvesting, to prepare the soil for the next planting period. Nitrogen, Phosphorus and Potassium are the main elements that need to be replaced after each vegetable is harvested. The following list provides the cost per kilogram as on 8 October 2009 of each of these necessary elements:

- Nitrogen - R 10.69/kg
- Phosphorus - R21.41/kg
- Potassium - R14.04/kg

The amount of nutrients to be replaced after each vegetable is harvested was obtained from 'Lantvoedingstowwe verwyder deur gewasse' used by a farmer called Michael Prinsloo who is a dedicated farmer and uses it on his own crops. Table 14 provides information on the amount of nutrients to be replaced after harvesting. The amount of nutrients removed from the soil (measured in kilogram per ton removed) was multiplied by the cost per kilogram of each nutrient to provide the price per ton crops removed.

The 'total expense per relative square meter area ratio' can now be determined. The total (R/ton) is measured by adding all of the different nutrient expenses. To determine the price per kilogram the amount (R/ton) can be divided by 1000. The 'total average kilogram per square meter' amount per vegetable was used to determine the total price per square meter. The relative square meter area ratio was again used to determine the 'Total expense per relative square meter area ratio'. Table 15 shows these calculations.

	Amount of Nitrogen, Phosphorus and Potassium removed from soil					
Vegetable	**Amount of nutrients removed from soil (kg/ton)**			**Price for nutrients which need to be replaced (R/ton)**		
Dark Green	**N**	**P**	**K**	**N**	**P**	**K**
Lettuce	2	0.3	3	R 21.38	R 6.42	R 42.12
Onions	3	0.5	3	R 32.07	R 10.71	R 42.12
Cucumber	1.4	2.2	1.4	R 14.97	R 47.10	R 19.66
Spinach	43	6	41	R 459.67	R 128.46	R 575.64
Broccoli	3	0.5	3.5	R 32.07	R 10.71	R 49.14
Garden peas	30	3	9	R 320.70	R 64.23	R 126.36
Cabbage	4	0.6	4.5	R 42.76	R 12.85	R 63.18
Red, Orange, Dark Yellow						
Tomatoes	3	0.7	4	R 32.07	R 14.99	R 56.16
Carrots	3.8	0.6	5	R 40.62	R 12.85	R 70.20
Peppers	2	**0.3**	**3**	R 21.38	R 6.42	R 42.12
Squash	**2.5**	0.35	3.1	R 26.73	R 7.49	R 43.52
Radish	24	2.3	22	R 256.56	R 49.24	R 308.88
Beet	4	0.5	5	R 42.76	R 10.71	R 70.20
Starchy						
Butternut	2.5	0.3	3.1	R 26.73	R 6.42	R 43.52
Sweet potatoes	2.9	0.2	1.5	R 31.00	R 4.28	R 21.06
Potatoes	5	0.8	7.5	R 53.45	R 17.13	R 105.30
Corn	15	3	4	R 160.35	R 64.23	R 56.16
Turnips	24	2.3	22	R 256.56	R 49.24	R 308.88
Pumpkin	2.5	0.3	3.1	R 26.73	R 6.42	R 43.52

Table 14: Amount of nutrient removed from the soil

Vegetable	Total amount of fertilizer needed to replace nutrients in the soil					
Dark Green	**Total (R/ton)**	**Total (R/kg)**	**Total (average kg/m^2)**	**Total (R/ m^2)**	**Relative square meter area ratio**	**Total expense per relative square meter area ratio**
Lettuce	R 69.92	R 0.07	7.75	R 0.54	19	R 10.30
Onions	R 84.90	R 0.08	5	R 0.42	17	R 7.22
Cucumber	R 81.72	R 0.08	1.15	R 0.09	6	R 0.56
Spinach	R 1,163.77	R 1.16	1.75	R 2.04	11	R 22.40
Broccoli	R 91.92	R 0.09	1.15	R 0.11	4	R 0.42
Garden peas	R 511.29	R 0.51	0.4	R 0.20	86	R 17.59
Cabbage	R 118.79	R 0.12	7	R 0.83	6	R 4.99
Red, Orange, Dark Yellow						
Tomatoes	R 103.22	R 0.10	3.1	R 0.32	10	R 3.20
Carrots	R 123.67	R 0.12	3.75	R 0.46	8	R 3.71
Peppers	R 69.92	R 0.07	3	R 0.21	11	R 2.31
Squash	R 77.74	R 0.08	2.25	R 0.17	18	R 3.15
Radish	R 614.68	R 0.61	1	R 0.61	36	R 22.13
Beet	R 123.67	R 0.12	3.25	R 0.40	17	R 6.83
Starchy						
Butternut	R 76.67	R 0.08	2.5	R 0.19	27	R 5.18
Sweet potatoes	R 56.34	R 0.06	21.3	R 1.20	1	R 1.20
Potatoes	R 175.88	R 0.18	10	R 1.76	4	R 7.04
Corn	R 280.74	R 0.28	2.25	R 0.63	16	R 10.11
Turnips	R 614.68	R 0.61	3.25	R 2.00	19	R 37.96
Pumpkin	R 76.67	R 0.08	2.5	R 0.19	21	R 4.03

Table 15: Total amount of fertilizer needed to replace nutrients in the soil

11.2.2.1.3 Pesticide expenses

The type of pesticide needed for the vegetables are very complex to determine. The following factors will determine which type of pesticide to use:

- the environment
- type of pests for the time of year
- the amount of time the vegetable must grow (some pesticides will lengthen the months to maturity)
- the type of weed in the region
- the time of year
- the type of fungus control needed
- the amount of pest control needed,
- the type of soil.

Due to the fact that the criteria for determining the type of pesticide to use are so broad, a specialist in this field needs to be consulted. The amount used for this project will be an average amount for all of the vegetables. The average price for pesticides per hectare is R700, thus the average amount per square meter will be 7c. Table 16 provides information on the total price that must be paid per relative square meter area ratio.

Dark Green	**Price (R/Sqm)**	**Relative square meter area ratio**	**Total (R/Rel sqm area ratio)**
Lettuce	R 0.07	19	R 1.33
Onions	R 0.07	17	R 1.19
Cucumber	R 0.07	6	R 0.42
Spinach	R 0.07	11	R 0.77
Broccoli	R 0.07	4	R 0.28
Garden peas	R 0.07	86	R 6.02
Cabbage	R 0.07	6	R 0.42
Red, Orange, Dark Yellow			
Tomatoes	R 0.07	10	R 0.70
Carrots	R 0.07	8	R 0.56
Peppers	R 0.07	11	R 0.77
Squash	R 0.07	18	R 1.26
Radish	R 0.07	36	R 2.52
Beet	R 0.07	17	R 1.19
Starchy			
Butternut	R 0.07	27	R 1.89
Sweet potatoes	R 0.07	1	R 0.07
Potatoes	R 0.07	4	R 0.28
Corn	R 0.07	16	R 1.12
Turnips	R 0.07	19	R 1.33
Pumpkin	R 0.07	21	R 1.47

Table 16: Price for pesticide per relative square meter area ratio

11.2.2.3 Variable planting expenses summary

The following total variable expenses must be deducted from the sales price, in order to find a value that can be used in the maximization formulation.

Vegetable	**Total amount for each vegetable (R/Relative square meter area ratio)**			
Dark Green	**Seed**	**Fertilizer**	**Pesticides**	**Total variable expenses**
Lettuce	R 22.60	R 10.30	R 1.33	R 34.22
Onions	R 18.84	R 7.22	R 1.19	R 27.24
Cucumber	R 8.88	R 0.56	R 0.42	R 9.86
Spinach	R 34.98	R 22.40	R 0.77	R 58.15
Broccoli	R 4.26	R 0.42	R 0.28	R 4.97
Garden peas	R 290.42	R 17.59	R 6.02	R 314.03
Cabbage	R 1.68	R 4.99	R 0.42	R 7.09
Red, Orange, Dark Yellow				
Tomatoes	R 24.51	R 3.20	R 0.70	R 28.41
Carrots	R 8.72	R 3.71	R 0.56	R 12.99
Peppers	R 34.20	R 2.31	R 0.77	R 37.28
Squash	R 4.17	R 3.15	R 1.26	R 8.58
Radish	R 64.67	R 22.13	R 2.52	R 89.32
Beet	R 8.48	R 6.83	R 1.19	R 16.50
Starchy				
Butternut	R 12.54	R 5.18	R 1.89	R 19.61
Sweet potatoes	R 2.10	R 1.20	R 0.07	R 3.37
Potatoes	R 5.60	R 7.04	R 0.28	R 12.92
Corn	R 2.94	R 10.11	R 1.12	R 14.17
Turnips	R 5.57	R 37.96	R 1.33	R 44.86
Pumpkin	R 4.87	R 4.03	R 1.47	R 10.36

Table 17: Total amount of variable selling expenses

11.2.2.4 Total planting profit

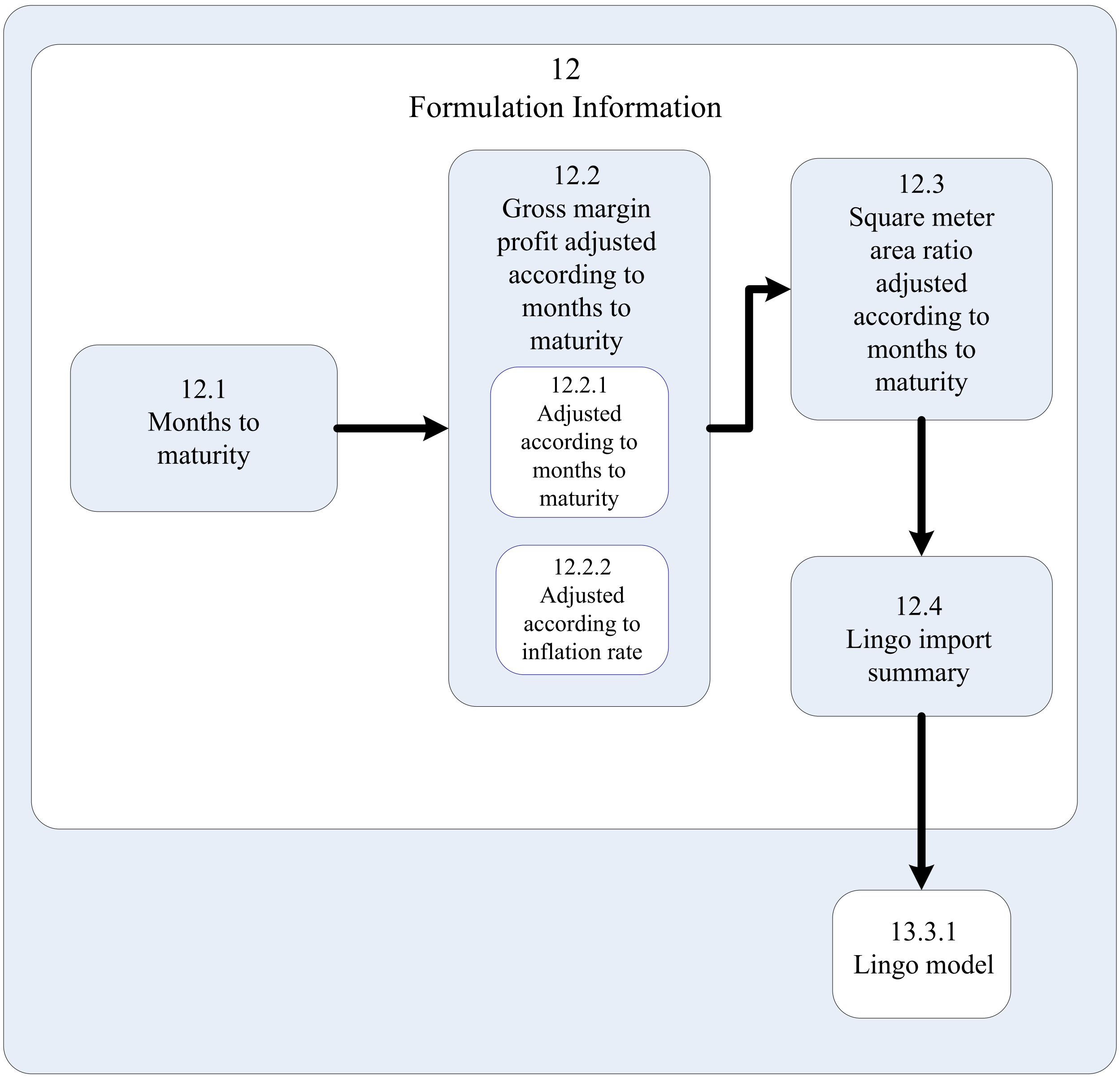
The total variable planting expenses per relative square meter area can now be deducted from the total market buying price per relative square meter area. These amounts will be used in the maximization recursion because it considers the market buying price, the total variable planting expenses, and are balanced according to the amount of nutrients, the weight of each vegetable per square meter, and amount of vegetables per square meter. The following table provides these amounts:

	Amount of benefit each relative square meter area will deliver		
Vegetable	**Sales - Market buying price (benefit) per Relative square meter**	**Total variable expenses**	**Gross margin before constant expenses**
Dark Green			
Lettuce	R 254.74	R 34.22	R 220.52
Onions	R 257.55	R 27.24	R 230.31
Cucumber	R 35.26	R 9.86	R 25.40
Spinach	R 67.38	R 58.15	R 9.23
Broccoli	R 15.81	R 4.97	R 10.85
Garden peas	R 338.15	R 314.03	R 24.12
Cabbage	R 49.14	R 7.09	R 42.05
Red, Orange, Dark Yellow			
Tomatoes	R 144.15	R 28.41	R 115.74
Carrots	R 67.20	R 12.99	R 54.21
Peppers	R 175.89	R 37.28	R 138.61
Squash	R 49.86	R 8.58	R 41.28
Radish	R 305.28	R 89.32	R 215.96
Beet	R 132.05	R 16.50	R 115.55
Starchy			
Butternut	R 155.93	R 19.61	R 136.31
Sweet potatoes	R 29.82	R 3.37	R 26.45
Potatoes	R 191.60	R 12.92	R 178.68
Corn	R 63.00	R 14.17	R 48.83
Turnips	R 187.72	R 44.86	R 142.86
Pumpkin	R 59.33	R 10.36	R 48.96

Table 18: Amount of gross profit margin before constant expenses

Chapter 5

Chapter 5 flow diagram



12 Formulation information

12.1 Months of maturity

The vegetable information needs to be adjusted according to the number of months the vegetables need to reach maturity. The reason for this is that you need to know how much you will gain in the number of months the vegetable needs to ripen. The market price can be agreed upon with the buyer when the vegetables are planted, but will only be ready to be sold after the number of months to maturity has elapsed. The following list provides information on the number of months each vegetable needs to reach maturity:

Average number of months each vegetable needs to reach maturity

- Dark Green
  - Lettuce - 3
  - Onions - 6
  - Cucumber - 2
  - Spinach - 4
  - Broccoli - 3
  - Garden peas - 3
  - Cabbage - 4
- Red, Orange, Dark Yellow
  - Tomatoes - 3
  - Carrots - 3
  - Peppers - 3
  - Squash - 2
  - Radish - 1
  - Beet - 2

- Starchy
  - Butternut - 3
  - Sweet potatoes - 4
  - Potatoes - 3
  - Corn - 4
  - Turnips - 3
  - Pumpkin - 5

12.2 Gross profit margins adjusted according to months to maturity

12.2.1 Adjusted according to months to maturity

The amount of profit that can be gained from each type of vegetable needs to be adjusted according to the amount of months it will need to reach maturity. The amount of gross profit margin was adjusted according to the amounts above minus 1. The reason for this is because vegetables are planted at the beginning of each month, and harvested at the end of each month. For instance, if Lettuce is to be planted in October the amount of benefit gained at the end of December will be 0. For Cucumber the amount to be gained at the end of November will be R9.23 per relative square meter area.

12.2.2 Adjusted according to inflation rate

A maximum amount of profit per month was determined. The market selling price will have a positive inflation rate according to the farmer and the variable planting expenses will have negative price inflation according to the farmer. As discussed in section 11.2.1 the positive price inflation will be 10% per year. In accordance the negative price inflation will be used as 5%. These values are not a true reflection but will only be used for the purpose of this project. As with the market buying price, the cost of fertilizer, seed and pesticides will differ each month, and will not necessarily comply with market trends. The amounts in table 19 were determined by the following equation, starting from October 2009: (Table 19 also considers section 12.2.1)

[Gross margin before constant expenses

+

Gross margin before constant expenses X positive inflation rate/12

-

Gross margin before constant expenses X negative inflation rate/12]

NB! [And all adjusted according to their unique months to maturity – 1]

		Gross margin before constant expenses (benefit, given planted each month) per Relative square meter given positive price inflation on income and negative price inflation on expenses (Estimated 10% on income and 5% on expenses)																	
Vegetables	**Starting price**	**2009**			**2010**												**2011**		
Dark Green		**Oct**	**Nov**	**Dec**	**Jan.**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Lettuce	220.52			0.00	0.00	0.00	223.28	224.20	225.12	0.00	226.95	227.87	228.79	229.71	230.63	0.00	0.00	0.00	234.30
Onions	230.31						0.00	0.00	0.00	0.00	234.15	235.11	0.00	237.03	0.00	0.00	0.00	0.00	0.00
Cucumber	25.40		25.40	25.51	25.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.56	26.67	26.78	26.88	0.00	0.00
Spinach	9.23				9.23	9.26	9.30	9.34	9.38	9.42	9.46	0.00	0.00	0.00	9.61	9.65	9.69	9.72	9.76
Broccoli	10.85			10.85	10.89	11.03	10.98	11.03	0.00	0.00	0.00	0.00	0.00	0.00	11.34	11.39	11.43	11.48	11.52
Garden peas	24.12			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.03	25.13	25.23	0.00	0.00	0.00	0.00
Cabbage	42.05				0.00	42.22	42.40	42.57	42.75	0.00	0.00	0.00	0.00	0.00	0.00	43.98	0.00	44.33	44.50
Red, Orange, Dark Yellow																			
Tomatoes	115.74			115.74	116.23	116.71	0.00	117.67	118.15	0.00	119.12	0.00	0.00	120.57	121.05	121.53	122.01	122.49	0.00
Carrots	54.21			54.21	0.00	0.00	54.88	55.11	55.34	0.00	0.00	56.01	56.24	56.47	59.27	56.92	0.00	0.00	57.59
Peppers	138.61			138.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	144.39	144.96	145.54	0.00	0.00	0.00
Squash	41.28		41.28	41.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.00	43.17	43.34	43.51	0.00	0.00	0.00
Radish	215.96	215.96	216.86	0.00	218.66	219.56	220.46	221.36	0.00	223.16	0.00	224.96	225.86	226.76	227.66	0.00	229.46	230.36	231.26
Beet	115.55		115.55	0.00	0.00	116.99	117.47	117.96	0.00	0.00	119.40	119.88	120.36	120.84	121.33	0.00	0.00	122.77	123.25
Starchy																			
Butternut	136.31			136.31	136.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	141.99	142.56	143.13	143.70	0.00	0.00
Sweet potatoes	26.45				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.44	27.55	0.00	0.00	0.00	0.00
Potatoes	178.68			178.68	0.00	0.00	180.92	181.66	182.41	0.00	0.00	0.00	0.00	0.00	186.87	187.62	0.00	0.00	189.85
Corn	48.83				48.83	49.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.87	51.07	51.28	51.48	0.00
Turnips	142.86			0.00	0.00	0.00	144.65	145.24	145.84	146.43	0.00	147.62	148.22	148.81	149.41	0.00	0.00	0.00	151.79
Pumpkin	48.96					48.96	49.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.20	51.41	51.61

Shaded box → Adapted according to the months to maturity less the month of harvest. (The month of harvest must be counted in because the crops will be harvested at the end of the month)

Table 19: Gross margin each month per relative square meter area after considering the effect inflation

12.3 Square meter area ratio adjusted according to months to maturity

The relative square meter area ratio given planted each month also needed to be adjusted according to the months each vegetable will take to reach maturity. All the same principles as mentioned in section 12.2 are applicable. The lesser grey area represents the amount of 'relative square meter area ratio' to be harvested at the end of the representing month. Table 20 shows the adjusted relative square meter area ratios:

Vegeatables		Relative square meter 'area' ratio given planted each month adjusted to 'months to maturity'																	
		2009			2010												2011		
Dark Green	Area 'ratio'	Oct	Nov	Dec	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lettuce	19			0	0	0	19	19	19	0	19	19	19	19	19	0	0	0	19
Onions	17						0	0	0	0	17	17	0	17	0	0	0	0	0
Cucumber	6		6	6	6	0	0	0	0	0	0	0	0	6	6	6	6	0	0
Spinach	11				11	11	11	11	11	11	11	0	0	0	11	11	11	11	11
Broccoli	11			11	11	11	11	11	0	0	0	0	0	0	11	11	11	11	11
Garden peas	86			0	0	0	0	0	0	0	0	0	86	86	86	0	0	0	0
Cabbage	6				0	6	6	6	6	0	0	0	0	0	0	6	0	6	6
Red, Orange, Dark Yellow																			
Tomatoes	10			10	10	10	0	10	10	0	10	0	0	10	10	10	10	10	0
Carrots	8			8	0	0	8	8	8	0	0	8	8	8	8	8	0	0	8
Peppers	11			11	0	0	0	0	0	0	0	0	0	11	11	11	0	0	0
Squash	18		18	18	0	0	0	0	0	0	0	0	18	18	18	18	0	0	0
Radish	36	36	36	0	36	36	36	36	0	36	0	36	36	36	36	0	36	36	36
Beets	17		17	0	0	17	17	17	0	0	17	17	17	17	17	0	0	17	17
Starchy																			
Butternut	27			27	27	0	0	0	0	0	0	0	0	27	27	27	27	0	0
Sweet potatoes	1				0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Potatoes	4			4	0	0	4	4	4	0	0	0	0	0	4	4	0	0	4
Corn	16				16	16	0	0	0	0	0	0	0	0	16	16	16	16	0
Turnips	19			0	0	0	19	19	19	19	0	19	19	19	19	0	0	0	19
Pumpkin	21					21	21	0	0	0	0	0	0	0	0	0	21	21	21

(Dark shaded cells) → Adapted according to the months to maturity less the month of harvest. (The month of harvest must be counted in because the crops will be harvested at the end of the month)

Table 20: The relative square meter area ratios adjusted to 'months to maturity'

12.4 Lingo import summary

The following 3 tables show a summary of all the values that need to be imported into the Lingo model. March 2010 was chosen as the starting point, due to the fact that it is the first month in which all of the information needed for the maximization formulation is known.

Lingo import schedule

	Lingo import schedule for the period March 2010 to June 2010											
Vegetable	**March '10**			**April '10**			**May '10**			**June '10**		
Dark Green	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm
Lettuce	223.28	19	3	224.20	19	3	225.12	19	3	0.00	0	3
Onions	0.00	0	6	0.00	0	6	0.00	0	6	0.00	0	6
Cucumber	0.00	0	2	0.00	0	2	0.00	0	2	0.00	0	2
Spinach	9.30	11	4	9.34	11	4	9.38	11	4	9.42	11	4
Broccoli	10.98	11	3	11.03	11	3	0.00	0	3	0.00	0	3
Garden peas	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Cabbage	42.40	6	4	42.57	6	4	42.75	6	4	0.00	0	4
Red, Orange, Dark Yellow												
Tomatoes	0.00	0	3	117.67	10	3	118.15	10	3	0.00	0	3
Carrots	54.88	8	3	55.11	8	3	55.34	8	3	0.00	0	3
Peppers	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Squash	0.00	0	2	0.00	0	2	0.00	0	2	0.00	0	2
Radish	220.46	36	1	221.36	36	1	0.00	0	1	223.16	36	1
Beets	117.47	17	2	117.96	17	2	0.00	0	2	0.00	0	2
Starchy												
Butternut	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Sweet potatoes	0.00	0	4	0.00	0	4	0.00	0	4	0.00	0	4
Potatoes	180.92	4	3	181.66	4	3	182.41	4	3	0.00	0	3
Corn	0.00	0	4	0.00	0	4	0.00	0	4	0.00	0	4
Turnips	144.65	19	3	145.24	19	3	145.84	19	3	146.43	19	3
Pumpkin	49.16	21	5	0.00	0	5	0.00	0	5	0.00	0	5

Table 21: Lingo import schedule for the period March 2010 to June 2010

	Lingo import schedule for the period July 2010 to October 2010											
Vegetable	**July '10**			**August '10**			**September '10**			**October '10**		
Dark Green	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm
Lettuce	226.95	19	3	227.87	19	3	228.79	19	3	229.71	19	3
Onions	234.15	17	6	235.11	17	6	0.00	0	6	237.03	17	6
Cucumber	0.00	0	2	0.00	0	2	0.00	0	2	26.56	6	2
Spinach	9.46	11	4	0.00	0	4	0.00	0	4	0.00	0	4
Broccoli	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Garden peas	0.00	0	3	0.00	0	3	25.03	86	3	25.13	86	3
Cabbage	0.00	0	4	0.00	0	4	0.00	0	4	0.00	0	4
Red, Orange, Dark Yellow												
Tomatoes	119.12	10	3	0.00	0	3	0.00	0	3	120.57	10	3
Carrots	0.00	0	3	56.01	8	3	56.24	8	3	56.47	8	3
Peppers	0.00	0	3	0.00	0	3	0.00	0	3	144.39	11	3
Squash	0.00	0	2	0.00	0	2	43.00	18	2	43.17	18	2
Radish	0.00	0	1	224.96	36	1	225.86	36	1	226.76	36	1
Beets	119.40	17	2	119.88	17	2	120.36	17	2	120.84	17	2
Starchy												
Butternut	0.00	0	3	0.00	0	3	0.00	0	3	141.99	27	3
Sweet potatoes	0.00	0	4	0.00	0	4	0.00	0	4	27.44	1	4
Potatoes	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Corn	0.00	0	4	0.00	0	4	0.00	0	4	0.00	0	4
Turnips	0.00	0	3	147.62	19	3	148.22	19	3	148.81	19	3
Pumpkin	0.00	0	5	0.00	0	5	0.00	0	5	0.00	0	5

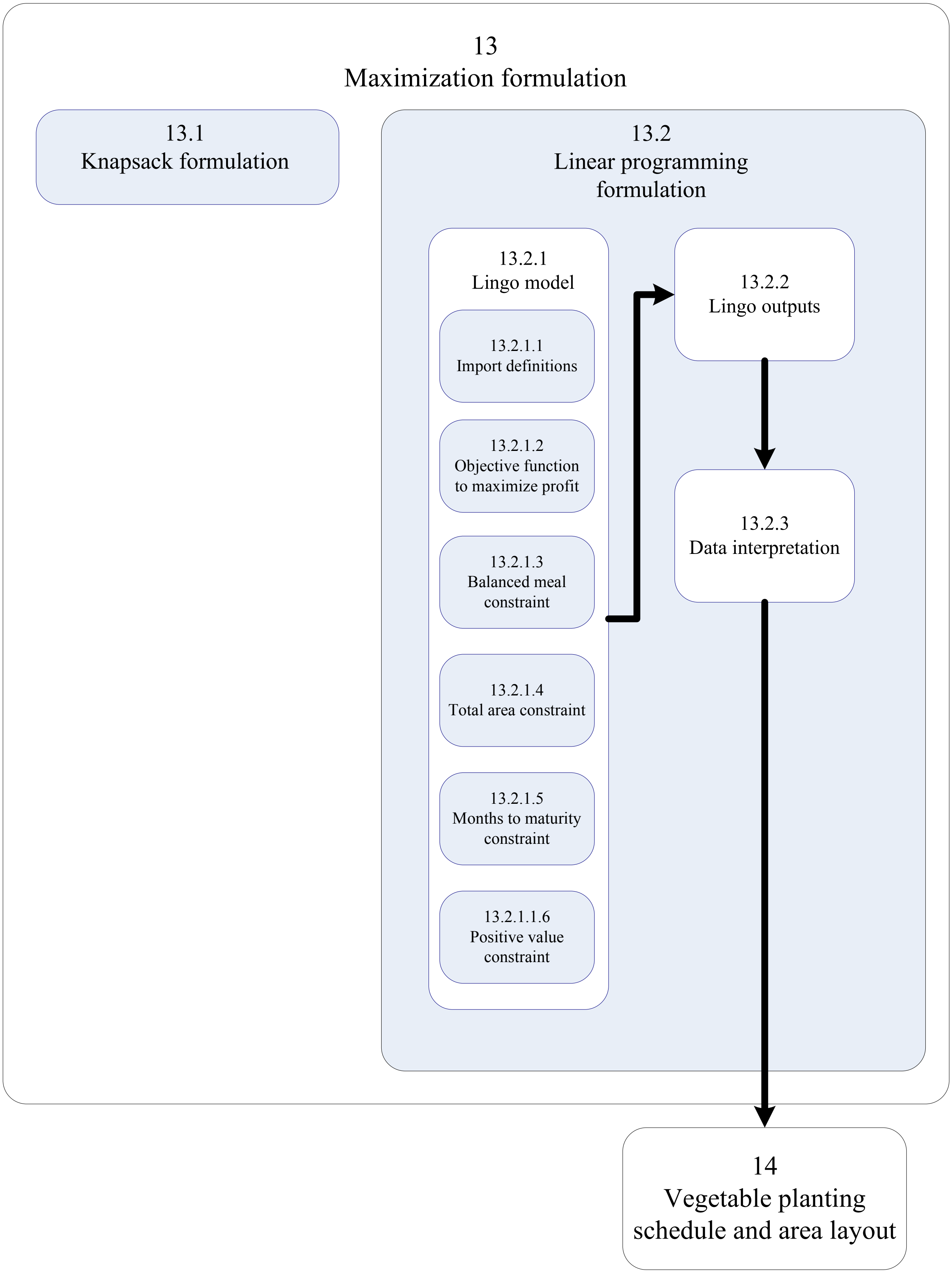
Table 22: Lingo import schedule for the period July 2010 to October 2010

	Lingo import schedule for the period November 2010 to March 2011														
Vegetable	**November '10**			**December '10**			**January '11**			**February '11**			**March '11**		
Dark Green	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm	Price	Area	Mtm
Lettuce	230.63	19	3	0.00	0	3	0.00	0	3	0.00	0	3	234.30	19	3
Onions	0.00	0	6	0.00	0	6	0.00	0	6	0.00	0	6	0.00	0	6
Cucumber	26.67	6	2	26.78	6	2	26.88	6	2	0.00	0	2	0.00	0	2
Spinach	9.61	11	4	9.65	11	4	9.69	11	4	9.72	11	4	9.76	11	4
Broccoli	11.34	11	3	11.39	11	3	11.43	11	3	11.48	11	3	11.52	11	3
Garden peas	25.23	86	3	0.00	0	3	0.00	0	3	0.00	0	3	0.00	0	3
Cabbage	0.00	0	4	43.98	6	4	0.00	0	4	44.33	6	4	44.50	6	4
Red, Orange, Dark Yellow															
Tomatoes	121.05	10	3	121.53	10	3	122.01	10	3	122.49	10	3	0.00	0	3
Carrots	59.27	8	3	56.92	8	3	0.00	0	3	0.00	0	3	57.59	8	3
Peppers	144.96	11	3	145.54	11	3	0.00	0	3	0.00	0	3	0.00	0	3
Squash	43.34	18	2	43.51	18	2	0.00	0	2	0.00	0	2	0.00	0	2
Radish	227.66	36	1	0.00	0	1	229.46	36	1	230.36	36	1	231.26	36	1
Beets	121.33	17	2	0.00	0	2	0.00	0	2	122.77	17	2	123.25	17	2
Starchy															
Butternut	142.56	27	3	143.13	27	3	143.70	27	3	0.00	0	3	0.00	0	3
Sweet potatoes	27.55	1	4	0.00	0	4	0.00	0	4	0.00	0	4	0.00	0	4
Potatoes	186.87	4	3	187.62	4	3	0.00	0	3	0.00	0	3	189.85	4	3
Corn	50.87	16	4	51.07	16	4	51.28	16	4	51.48	16	4	0.00	0	4
Turnips	149.41	19	3	0.00	0	3	0.00	0	3	0.00	0	3	151.79	19	3
Pumpkin	0.00	0	5	0.00	0	5	51.20	21	5	51.41	21	5	51.61	21	5

Table 23: Lingo import schedule for the period November 2010 to March 2011

Chapter 6

Chapter 6 flow diagram



13 Maximization formulation

The main objective of this project is to find a solution that can make the farm at Nellmapius self sustainable, while providing a healthy diet to people. According to this philosophy the objective function, the amount of profit, needs to be maximized. The reason for this is the fact that they first need self sustainability, and then a balanced meal per day for each person.

13.1 Deterministic dynamic programming 'Knapsack' formulation

A deterministic dynamic programming 'Knapsack' formulation was formulated. The problem with this formulation was the fact that there were 19 stages (representing the number of vegetables) and 12500 states (representing the number of square meters). For the deterministic dynamic program to maximize each stage and state, each stage and state would have to perform - the total area for the specific subgroup divided by the amount of relative square meter ratio's – amount of calculations inside each stage and state. For the next state this value will be one less than the previous state. This recursion was formulated but the runtime of the Matlab program would have taken too long to calculate the solution. This program had to be repeated 13 times to determine the maximum amounts for each month from March 2010 to March 2011.

The deterministic dynamic program, called the 'Knapsack' formulation works on the principle of having for instance a bag or knapsack, which must be filled with the optimal items. Each item that must fit into the bag has a weight constraint and a benefit amount assigned to it. The program determines the optimal way in which to pack the knapsack, maximizing the amount of benefit gained from the items chosen. The principle of this deterministic dynamic programming 'Knapsack' formulation can be applied to a piece of land, where you have the different vegetables as stages, and the amount of square meter left to be planted as the states. The only problem is the size of the piece of land. This would have resulted in more or less 1 billion calculations for each month.

13.2 Linear programming formulation

A linear program was formulated that would result in the same answer as the deterministic dynamic ‘Knapsack’ program. Each vegetable will have an amount of benefit and area constraint assigned to it. The benefit (‘Gross margin before constant expenses’) and the weight (‘Relative square meter area ratio’) will be assigned to each vegetable. The objective function will be maximized with the amount of square meter area ratio’s chosen multiplied with the corresponding Gross margin before constant expenses’ for that specific vegetable. The ‘weight’ value (‘Relative square meter area ratio’) assigned to each vegetable will result in a minimization factor in the area constraint (These constraints were discussed in chapter 4 in section 11.1.1.1 and 11.1.1.2). If the relative square meter ratio for that specific vegetable is very high, it will be less favorable to be chosen. A linear programming formulation is much more straightforward, easier to formulate, less complex when explaining to people and would result in the same answer.

13.2.1 Lingo model

13.2.1.1 Import definitions

Lingo was used to solve the linear formulation. The following abbreviations were used in the formulation:

Abbreviations:

dg	-	Dark green vegetables
rody	-	Red, Orange and Dark yellow vegetables
s	-	Starchy vegetables

nx1 Matrixes

i	-	1X7 Matrix representing Dark green vegetables
j	-	1x6 Matrix representing Red, Orange and Dark yellow vegetables
k	-	1x6 Matix representing Starchy vegetables

The matrices in the Excel formulation called the 'Lingo import schedule' were used separately each month for each vegetable subgroup. The sequence of inputs was used as in the Excel formulation. The sequence is the price or profit per vegetable (price), the relative square meter area ratio (area ratio) and the amount of months to maturity (mtm). The people at Nellmapius have 5 hectares of land available to plant. This amount was divided by 4 to be able to have 4 'time slots' in order to have matured vegetables each month. The time schedule will be discussed in Chapter 7. The total area available each month is 1.25 hectares or 12500 square meter.

13.2.1.2 Objective function to maximize profits

Objective function : Maximization

$$\max z = \sum_{i=1}^{7} \left(price_{dg_i} \times \text{amount to be planted}_{dg_i} \right) + \sum_{j=1}^{6} \left(price_{rody_j} \times \text{amount to be planted}_{rody_j} \right) + \sum_{k=1}^{6} \left(price_{s_k} \times \text{amount to be planted}_{s_k} \right)$$

13.2.1.3 Balanced meal constraint

Subject to: Constraints

Balanced meal constraint

Dark green vegetables must represent 27.54% of the total area

$$\sum_{i=1}^{7}\left(area\ ratio_{dg_i} \times \text{amount to be planted}_{\text{dg}_i}\right) \geq 0.2754 \times \text{total area}$$

Red, Orange and Dark Yellow vegetables must represent 20.36% of the total area

$$\sum_{j=1}^{6}\left(area\ ratio_{rody_j} \times \text{amount to be planted}_{\text{rody}_j}\right) \geq 0.2036 \times \text{total area}$$

Starchy vegetables must represent 50.10% of the total area

$$\sum_{k=1}^{6}\left(area\ ratio_{s_k} \times \text{amount to be planted}_{s_k}\right) \geq 0.5210 \times \text{total area}$$

13.2.1.4 Total area constraint

Total area constraint

Area amounts must be smaller or equal to the total area

$$\sum_{i=1}^{7}\left(area\,ratio_{dg_i} \times \text{amount to be planted}_{\text{dg}_i}\right) +$$

$$\sum_{j=1}^{6}\left(area\,ratio_{rody_j} \times \text{amount to be planted}_{\text{rody}_j}\right) +$$

$$\sum_{k=1}^{6}\left(area\,ratio_{s_k} \times \text{amount to be planted}_{s_k}\right) \leq \text{total area}$$

13.2.1.5 Months to maturity constraint

Months to maturity

The months to maturity constraint will only be used when there isn't sufficient space in the vegetable planting schedule

$$months\ to\ maturity_{dg\ i} \leq amount\ of\ months\ open\ on\ the\ vegetable\ planting\ scheduled_{dg\ i}$$

∀ i = 1:7

$$months\ to\ maturity_{rody\ j} \leq amount\ of\ months\ open\ on\ the\ vegetable\ planting\ scheduled_{rody\ j}$$

∀ j = 1:6

$$months\ to\ maturity_{s\ k} \leq amount\ of\ months\ open\ on\ the\ vegetable\ planting\ scheduled_{s\ k}$$

∀ k = 1:6

13.2.1.6 Positive value constraint

Positive integer constraint

$\text{amount to be planted}_{dg_i} \geq 0$ ∀ i = 1:7

$\text{amount to be planted}_{rody_j} \geq 0$ ∀ j = 1:6

$\text{amount to be planted}_{s_k} \geq 0$ ∀ k = 1:6

13.2.2 Lingo outputs

The output that was determined by the Lingo formulation supplies the amount of relative square meter areas to be harvested at the end of its months to maturity. Table 24 provides these maximum relative square meter amounts.

NB! None of the starches represented in this project can be harvested in July (The light grey area). This is a very unique case because none of the starchy vegetables can be planted according to their respective months to maturity in advance to July. This creates a problem when the people need to be fed according to the balanced meal diet. A solution to this problem will probably be to sell all the excess lettuce, and buy starch for the people to eat, to recover their balanced diet.

	Number of area ratio's to be harvested at the end of each month according to Maximization of profits												
Vegetable	**2010**										**2011**		
Dark Green	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Lettuce	181.18	181.18	181.18		523.95	181.18	181.18		181.18				181.18
Onions								202.50					
Cucumber											573.75		
Spinach				312.95									
Broccoli													
Garden peas													
Cabbage										573.75		573.75	
Red, Orange, Dark Yellow													
Tomatoes		254.50	254.50		254.50						254.50	254.50	
Carrots													
Peppers								231.36	231.36	231.36			
Squash													
Radish				70.69									
Beets	149.71					149.71	149.71						149.71
Starchy													
Butternut											241.20		
Sweet potatoes								6512.50					
Potatoes	1628.13	1628.13	1628.13						1628.13	1628.13			1628.13
Corn												407.03	
Turnips				342.76		342.76	342.76						
Pumpkin													

Figure 24: The number of square meter areas that can be harvested each month according to maximization of profits

13.2.3 Data interpretation

According to the global optimal solution 181.18 square meter ratios of Lettuce, 149.71 square meter ratios of Carrots and 1628.13 square meter ratios of Potatoes must be planted in January. These values need to be transformed back to the amount of square meters.

The output values must be multiplied by the 'Relative square meter area ratio' in order to determine the amount of square meters to plant. Table 25 shows the amounts and types of vegetables that must be planted to be harvested in the following months:

Vegetable		Number of square meters to be harvested according to Maximization of profits												
		2010										2011		
Dark Green	**Area ratio**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Lettuce	19	3442.5	3442.5	3442	0	9955	3442.5	3442.5	0	3442.5	0	0	0	3442.5
Onions	17	0	0	0	0	0	0	0	3442.5	0	0	0	0	0
Cucumber	6	0	0	0	0	0	0	0	0	0	0	3442.5	0	0
Spinach	11	0	0	0	3442.5	0	0	0	0	0	0	0	0	0
Broccoli	11	0	0	0	0	0	0	0	0	0	0	0	0	0
Garden peas	86	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage	6	0	0	0	0	0	0	0	0	0	3442.5	0	3442.5	0
Red, Orange, Dark Yellow														
Tomatoes	10	0	2545	2545	0	2545	0	0	0	0	0	2545	2545	0
Carrots	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Peppers	11	0	0	0	0	0	0	0	2545	2545	2545	0	0	0
Squash	18	0	0	0	0	0	0	0	0	0	0	0	0	0
Radish	36	0	0	0	2545	0	0	0	0	0	0	0	0	0
Beets	17	2545	0	0	0	0	2545	2545	0	0	0	0	0	2545
Starchy														
Butternut	27	0	0	0	0	0	0	0	0	0	0	6512.5	0	0
Sweet potatoes	1	0	0	0	0	0	0	0	6512.5	0	0	0	0	0
Potatoes	4	6512.5	6512.5	6513	0	0	0	0	0	6512.5	6512.5	0	0	6512.5
Corn	16	0	0	0	0	0	0	0	0	0	0	0	6512.5	0
Turnips	19	0	0	0	6512.5	0	6512.5	6512.5	0	0	0	0	0	0
Pumpkin	21	0	0	0	0	0	0	0	0	0	0	0	0	0
Total area		12500	12500	12500	12500	12500	12500	12500	12500	12500	12500	12500	12500	12500

Table 25: Number of square meter to be harvested according to maximization of profits

14 Vegetable planting schedule

A vegetable planting schedule was created. If the months to maturity for each vegetable are taken into account, the schedule can be ‘packed’ in reverse starting from March 2010 with Lettuce. Lettuce takes three months to reach maturity, so if it is to be harvested at the end of March 2010, it must be planted at the beginning of January 2010. This was performed for each month and each vegetable subgroup according to their unique amount of months to maturity.

14.1 Vegetable planting schedule structure

The 4 rows in each vegetable subgroup represent the specific area in which it must be planted. The reason for dividing each vegetable subgroup area into 4 is that it is the average amount of months to maturity. This was done to minimize the risk of trying to plant certain vegetables which will overlap with others.

If an area needed to be chosen the first option was to choose an area that was harvested the previous month. The reason for this is to leave enough time open for the next months’ vegetables, which might need more time to reach maturity. If the vegetables can’t be planted on an area directly after that area was harvested, another area must be identified. The area with the most open ‘time’ or months must then be chosen. This ensures that if something else must be planted on a different time on that same area that was chosen, the probability will be higher that the vegetable - which can generate the most profit - can be planted, because the ‘open’ months are more. An example will be Peppers that must be harvested at the end of October 2010. Area no. 4 was chosen instead of area no. 1. The reason for this is that after maximization there is some space left to plant anything. These areas per month will be wasted for if not used. The reason why there isn’t anything assigned to these areas in the specific months, is because a balanced meal needs to be deducted from the total area, and everything must be in balance according to the vegetable subgroup percentages. The open space can be used to plant the most profitable vegetable, in order to generate enough funds to be able to feed more people as well as cover more expenses if necessary. Schedule 1 provides a balanced schedule of planting and harvesting times, and Figure 5 shows the area layout for March 2010.

<table>
<tr><th colspan="2"></th><th colspan="15">Vegetable planting and harvesting schedule from January 2010 to March 2011</th></tr>
<tr><th colspan="2"></th><th colspan="12">2010</th><th colspan="3">2011</th></tr>
<tr><th>Vegetables</th><th>Area no</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th></tr>
<tr><td rowspan="4">Dark green</td><td>1</td><td colspan="3">Lettuce</td><td></td><td colspan="6">Onions</td><td colspan="4">Cabbage</td><td></td></tr>
<tr><td>2</td><td></td><td colspan="3">Lettuce</td><td colspan="3">Lettuce</td><td></td><td colspan="4">Cabbage</td><td colspan="3">Lettuce</td></tr>
<tr><td>3</td><td></td><td></td><td colspan="3">Lettuce</td><td colspan="3">Lettuce</td><td colspan="3">Lettuce</td><td colspan="2">Cucumber</td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td colspan="4">Spinach</td><td colspan="3">Lettuce</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Red, Orange and Dark Yellow</td><td>1</td><td></td><td colspan="2">Beets</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td colspan="3">Tomatoes</td><td colspan="3">Tomatoes</td><td colspan="2">Beets</td><td colspan="3">Peppers</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td colspan="3">Tomatoes</td><td>Radish</td><td colspan="2">Beets</td><td colspan="3">Peppers</td><td colspan="3">Tomatoes</td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">Peppers</td><td colspan="3">Tomatoes</td><td colspan="2">Beets</td></tr>
<tr><td></td><td>4</td><td colspan="15"></td></tr>
<tr><td rowspan="4">Starchy</td><td>1</td><td colspan="3">Potatoes</td><td></td><td></td><td></td><td colspan="4">Sweet potatoes</td><td colspan="3">Butternut</td><td></td><td></td></tr>
<tr><td>2</td><td></td><td colspan="3">Potatoes</td><td colspan="3">Lettuce</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td colspan="3">Potatoes</td><td colspan="3">Turnips</td><td colspan="3">Potatoes</td><td colspan="3">Butternut</td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td colspan="3">Turnips</td><td colspan="3">Turnips</td><td colspan="3">Potatoes</td><td colspan="3">Potatoes</td></tr>
</table>

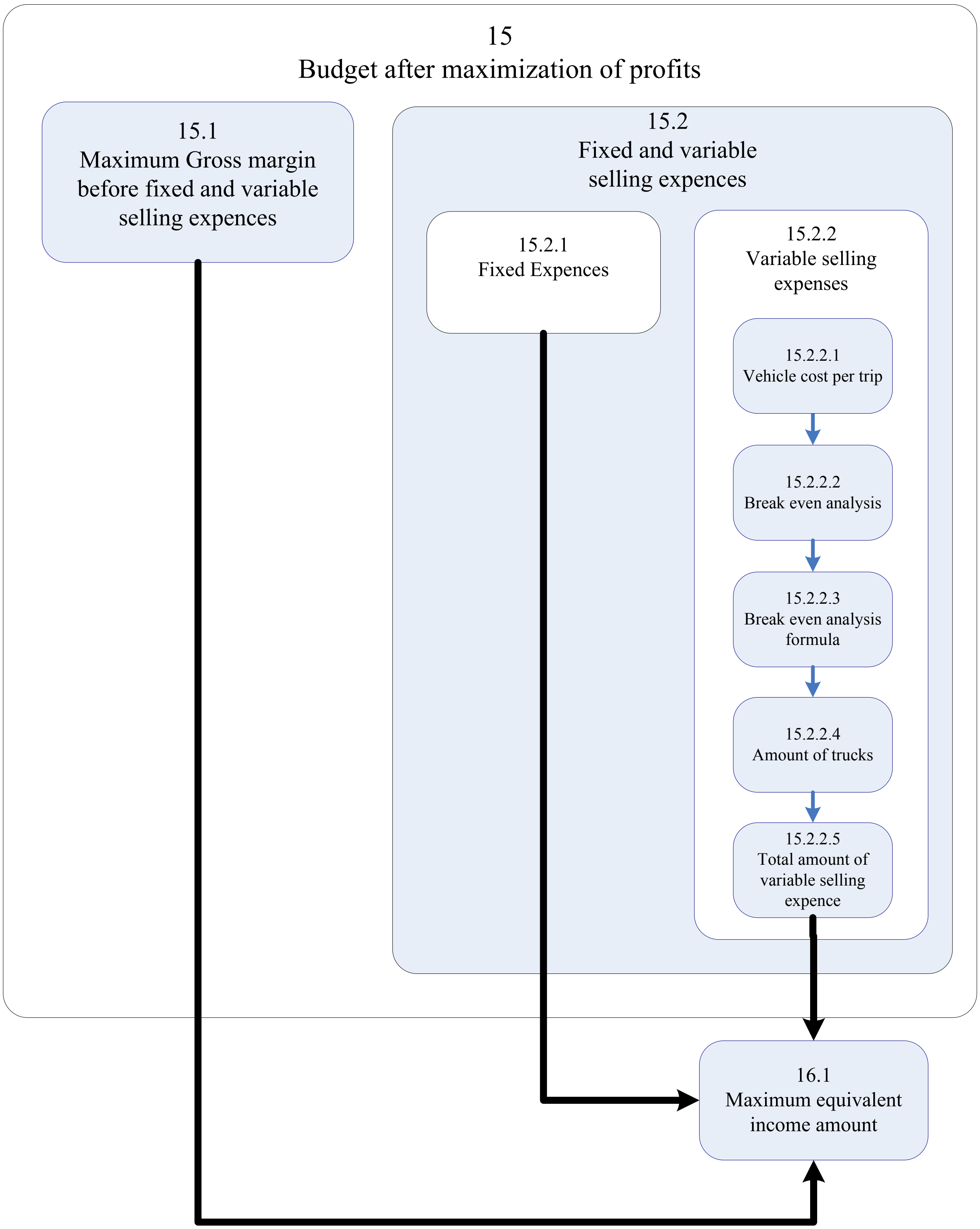
Figure 5: Vegetable planting and harvesting schedule from January 2010 to March 2011

<table>
<tr><th colspan="4">Area layout for the end of March 2010</th></tr>
<tr><td>dg_area no 1: Lettuce (ready to be harvested)</td><td>dg_area no 2: Lettuce</td><td rowspan="2">s_area no 1: Potatoes (ready to be harvested)</td><td rowspan="2">s_area no 2: Potatoes</td></tr>
<tr><td>dg_area no 3: Lettuce</td><td>dg_area no 4: Spinach</td></tr>
<tr><td>rody_area no 1: Beets (ready to be harvested)</td><td>rody_area no 2: Tomatoes</td><td rowspan="2">s_area no 3: Potatoes</td><td rowspan="2">s_area no 4: Vacant</td></tr>
<tr><td>rody_area no 3: Tomatoes</td><td>rody_area no 4: Vacant</td></tr>
</table>

Figure 6: Area layout for the end of March 2010

Chapter 7

Chapter 7 flow diagram



15 Budget after maximization of profits

15.1 Maximum Gross margin before fixed and variable selling expenses

The maximum amount of profits (assuming all surplus is sold) can now be determined. This value will be determined by multiplying the maximum 'number of square meter area ratios' with the amount of 'Gross margin per month' before 'constant expenses per relative square meter given price inflation', as shown in table 19 in section 12.2.2. The sum of all these values had to be the same as the Global Optimal solution provided by the Lingo maximization output. The following table provides the raw maximum gross margin, if everything were to be sold, and there were no extra expenses.

	Amount of Gross margin (R) to be earned according to Maximization of profits												
	2010										2011		
Vegetable	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Dark Green													
Lettuce	40454	40621	40787	0	118911	41287	41453	0	41786	0	0	0	42452
Onions	0	0	0	0	0	0	0	47998	0	0	0	0	0
Cucumber	0	0	0	0	0	0	0	0	0	0	15423	0	0
Spinach	0	0	0	2947	0	0	0	0	0	0	0	0	0
Broccoli	0	0	0	0	0	0	0	0	0	0	0	0	0
Garden peas	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage	0	0	0	0	0	0	0	0	0	25231	0	25432	0
Red, Orange, Dark Yellow													
Tomatoes	0	29948	30070	0	30316	0	0	0	0	0	31052	31175	0
Carrots	0	0	0	0	0	0	0	0	0	0	0	0	0
Peppers	0	0	0	0	0	0	0	33406	33539	33673	0	0	0
Squash	0	0	0	0	0	0	0	0	0	0	0	0	0
Radish	0	0	0	15776	0	0	0	0	0	0	0	0	0
Beets	17587	0	0	0	0	17947	18019	0	0	0	0	0	18452
Starchy													
Butternut	0	0	0	0	0	0	0	0	0	0	34661	0	0
Sweet potatoes	0	0	0	0	0	0	0	178714	0	0	0	0	0
Potatoes	294558	295770	296982	0	0	0	0	0	304255	305467	0	0	309104
Corn	0	0	0	0	0	0	0	0	0	0	0	20953	0
Turnips	0	0	0	50192	0	50600	50804	0	0	0	0	0	0
Pumpkin	0	0	0	0	0	0	0	0	0	0	0	0	0
Gross margin per month	**352599**	**366338**	**367840**	**68916**	**149227**	**109834**	**110276**	**260118**	**379581**	**364372**	**81136**	**77561**	**370008**

Table 26: Maximum gross margin to be earned each month

15.2 Fixed and variable selling expenses

There are a few expenses that need to be deducted after the amount of possible income was calculated. These expenses are fixed expenses per month such as labour expense and fixed expenses per year such as tools and equipment. Variable selling expenses are the delivery to the market. All of these expenses can only be deducted after the maximization solution has been found.

15.2.1 Fixed Expenses

Fixed expenses are deducted per month for labour, and per year for tools and equipment. The fixed amount of expenses per month can be calculated. The assumption will be made that no salary increase will be made for the specified time period, only afterwards, and that the expense for tools and equipment won't increase in the specified time period. The following table provides information on the amount of fixed expenses per year:

Fixed expenses (per month)		**Worker salary**	**Amount**	**Total**	**Total per month**
	Labour expenses	R 1,200.00	10	R 12,000.00	R 12,000.00
Fixed expenses (once a year)		**Per unit-worker**	**Amount**	**Total**	**Total per month**
	Tools and equipment	R 2,000.00	10	R 20,000.00	R 1,666.67
Fixed expenses per month					**R 13,666.67**

Table 27: Fixed expenses per month

15.2.2 Variable selling expenses

Vegetables need to be sold each month in order to generate enough funds to pay for fixed and variable selling expenses. Since variable planting expenses was deducted before maximization which decreased the gross profit margin, only fixed and variable selling expenses will be taken into account at this stage. The main problem with variable selling expenses is the fact that the amount of trucks will vary for the amount of vegetables to be sold. The explanation for this is the following: A fixed amount of vegetables for each month individually needs to be sold in order to cover the fixed expenses. Trucks need to be rented, or a delivery service needs to be used in order to deliver the vegetables to the market. The fixed expenses will be covered by the amount of vegetables to be sold. The problem is that the trucks don't run on water and this expense needs to be covered by selling more vegetables. If more vegetables are to be sold to cover for the truck expenses, more trucks are needed to deliver the vegetables to the market. This will keep on happening until a break even point is established. A Break Even Analysis was performed to determine the amount of trucks needed to deliver all of the vegetables to the market.

The following is a geographical map showing the total distance of 73.03 kilometers that the trucks must travel from Nellmapius to the 'Johannesburg Fresh Produce Market' situated at City Deep, Johannesburg.

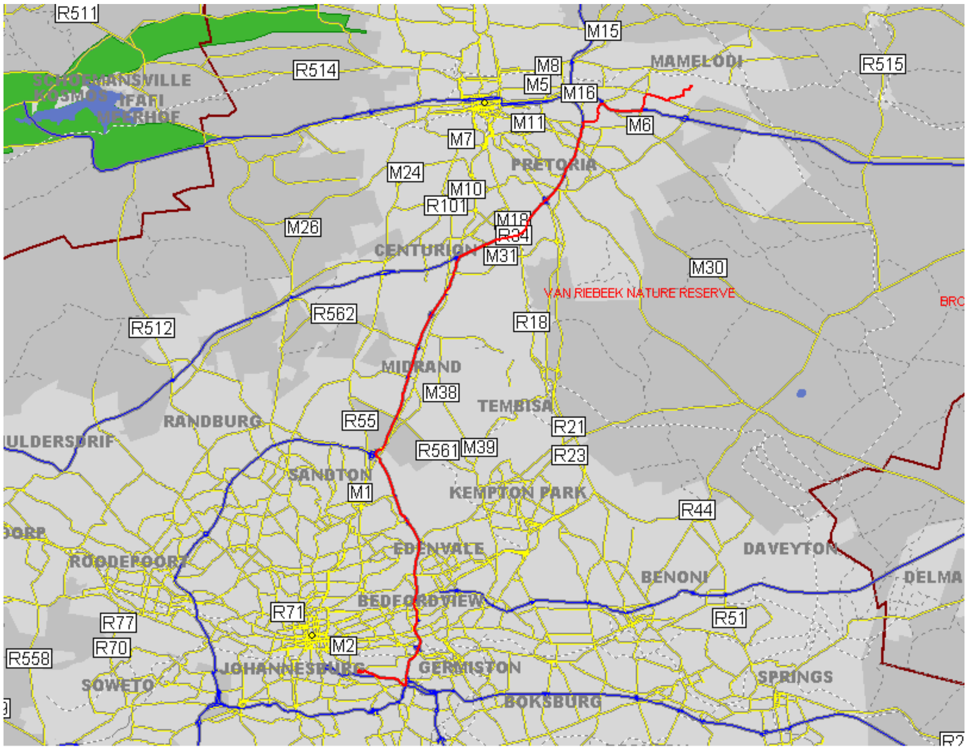


Figure 7: Total distance from Nellmapius to JFPM (73.03km)

15.2.2.1 Vehicle cost per trip

The following prices per kilometer are according to AA rates. The trucks that will be used are 0.5 Ton and 1 Ton trucks. The 1 Ton truck is cheaper over the total distance in comparison to the 0.5 Ton truck. The 1 ton truck will be used to determine the amount of trucks needed. If the amount of trucks needed at the end of the break even analysis is a fraction below 0.5, a 0.5 ton truck will be used plus the amount of 1 ton trucks needed. The reason for this is when determining the expense for the amount of trucks to be used; the 0.5 ton truck will then decrease the amount of expense for delivering the vegetables to the market. This will be shown later on in this chapter.

	Variable expense per truck trip	
Capacity of truck	0.5 Ton	1 Ton
Tariffs per km	R 3.61	R 5.67
Total distance needed to travel	73.03	73.03
Tariff per trip	R 263.64	**R 414.08**

Table 28: Variable expenses per truck trip

15.2.2.2 Break even analysis

In order to perform a break even analysis to determine the number of trucks to use, the sales price, variable expenses, fixed expenses and amount of profit needed must be known. In this case no profit will be made from selling the vegetables, so the profit in each equation will be 0. The sales price needs to be determined per ton. The sales prices per kilogram as shown in Table 5 must be multiplied by 1000 to determine the market buying price per ton. The following table shows these market buying prices:

Vegetable	**Market buying price as on 23 Sept 2009 at 13H00**	
Dark Green	**Per kilogram**	**Per ton**
Lettuce	R 1.73	R 1,730.00
Onions	R 3.03	R 3,030.00
Cucumber	R 5.11	R 5,110.00
Spinach	R 3.50	R 3,500.00
Broccoli	R 1.25	R 1,250.00
Garden peas	R 9.83	R 9,830.00
Cabbage	R 1.17	R 1,170.00
Red, Orange, Dark Yellow		
Tomatoes	R 4.65	R 4,650.00
Carrots	R 2.24	R 2,240.00
Peppers	R 5.33	R 5,330.00
Squash	R 2.30	R 2,300.00
Radish	R 8.48	R 8,480.00
Beet	R 2.39	R 2,390.00
Starchy		
Butternut	R 2.31	R 2,310.00
Sweet potatoes	R 1.40	R 1,400.00
Potatoes	R 4.79	R 4,790.00
Corn	R 1.75	R 1,750.00
Turnips	R 3.04	R 3,040.00
Pumpkin	R 1.13	R 1,130.00

Table 29: Market buying price per ton

These amounts need to be translated into truck size amounts. Each of the vegetable prices is measured in price per ton. In order to keep the balance according to the amount of vegetables that need to be subtracted from the land, the truck loads must also be in the same ratio as the vegetable area that was planted. The trucks' capacity, as with the balanced meal each day and the area, must be divided into the 'vegetable subgroup percentage ratios'. This will result in the price per ton for each vegetable per ton to be multiplied by the vegetable subgroup amount as can be seen in section 11.1.1.1. This will ensure that the vegetables will be sold in the same ratio as it was planted, and must be eaten. The values in the following table was determined by multiplying the price that can be gained from selling 1 ton of each vegetable with the balanced meals percentage, in order reach a balanced price according to the amount that can fit into a 1 ton truck.

Vegetable	**Selling price for the end of October 2010 of vegetables fitting into a 1 Ton truck to be used in Break even analysis**		
Dark Green	**Per ton**	**Balanced meal or capacity percentage**	**Per balanced truck capacity**
Lettuce	R 1,730.00	0.2754	R 476.44
Onions	R 3,030.00	0.2754	R 834.46
Cucumber	R 5,110.00	0.2754	R 1,407.29
Spinach	R 3,500.00	0.2754	R 963.90
Broccoli	R 1,250.00	0.2754	R 344.25
Garden peas	R 9,830.00	0.2754	R 2,707.18
Cabbage	R 1,170.00	0.2754	R 322.22
Red, Orange, Dark Yellow			
Tomatoes	R 4,650.00	0.2036	R 946.74
Carrots	R 2,240.00	0.2036	R 456.06
Peppers	R 5,330.00	0.2036	R 1,085.19
Squash	R 2,300.00	0.2036	R 468.28
Radish	R 8,480.00	0.2036	R 1,726.53
Beet	R 2,390.00	0.2036	R 486.60
Starchy			
Butternut	R 2,310.00	0.521	R 1,203.51
Sweet potatoes	R 1,400.00	0.521	R 729.40
Potatoes	R 4,790.00	0.521	R 2,495.59
Corn	R 1,750.00	0.521	R 911.75
Turnips	R 3,040.00	0.521	R 1,583.84
Pumpkin	R 1,130.00	0.521	R 588.73

Table 30: Selling price of vegetables fitting into a 1 Ton truck to be used in Break even analysis

The number of trucks to be used each month can now be determined with the break even analysis. The following table is a summary of all the income and expenses for the month of March 2010. The vegetables to be harvested are Lettuce, Beet and Potatoes.

Summary of Break even analysis inputs for March 2010		**vegetable**
Sales income per truck	R 488.35	Lettuce
	R 502.82	Beets
	R 2,557.98	Potatoes
Total sales income per truck	**R 3,549.15**	
Variable selling expenses per truck	**R 414.08**	
Fixed expenses	**R 13,666.67**	

Table 31: Summary of Break even analysis inputs for March 2010

15.2.2.3 Break even analysis formula

Formula:

Sales income x amount of trucks needed =

Variable selling expense x amount of trucks needed

+

Fixed expense

This formula can be shuffled around to determine the amount of trucks needed:

$$\textbf{Amount of trucks needed} = \frac{\textbf{Fixed expense}}{\textbf{Sales income - Variable selling expense}}$$

Table 31 shows the total sales income per month given that a different combination of vegetables was harvested each month. The amounts in Table 32 had to be adapted according to the positive price inflation as can be seen in section 11.2.1 and Table 12. The reason for this is because we have a recent market buying price, and we need the market buying price of March 2010 to March 2011.

Vegetable	The total sales income plus positive price inflation that can be generated per truck given the types of vegetables it will deliver												
	2010										2011		
Dark Green	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lettuce	488.35	492.32	496.29	0.00	504.23	508.20	512.17	0.00	520.11	0.00	0.00	0.00	536.00
Onions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	883.14	0.00	0.00	0.00	0.00	0.00
Cucumber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1571.47	0.00	0.00
Spinach	0.00	0.00	0.00	1004.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Broccoli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garden peas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cabbage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	351.76	0.00	357.13	0.00
Red, Orange, Dark Yellow													
Tomatoes	0.00	978.30	986.19	0.00	1001.97	0.00	0.00	0.00	0.00	0.00	1049.30	1057.19	0.00
Carrots	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peppers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1175.62	1184.67	1193.71	0.00	0.00	0.00
Squash	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Radish	0.00	0.00	0.00	1841.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beet	502.82	0.00	0.00	0.00	0.00	523.10	527.15	0.00	0.00	0.00	0.00	0.00	551.48
Starchy													
Butternut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1333.89	0.00	0.00
Sweet potatoes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	784.11	0.00	0.00	0.00	0.00	0.00
Potatoes	2557.98	2578.78	2599.57	0.00	0.00	0.00	0.00	0.00	2724.35	2745.15	0.00	0.00	2807.54
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1010.52	0.00
Turnips	0.00	0.00	0.00	1663.03	0.00	1689.43	1702.63	0.00	0.00	0.00	0.00	0.00	0.00
Pumpkin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total sales per truck	3549.15	4049.40	4082.05	4508.73	1506.20	2720.73	2741.95	2842.86	4429.13	4290.61	3954.67	2424.84	3895.01

Table 32: The total sales income that can be generated per truck given the types of vegetables it will deliver

15.2.2.4 Amount of trucks to use

The following is the calculation that was performed to determine the amount of trucks to use at the end of March 2010:

$$\textbf{Amount of trucks needed} = \frac{13\ 666.67}{3\ 549.15 - 414.08}$$

$$= 4.36$$

The following table shows the break even number of trucks needed to deliver the vegetables to the market:

	Break even amount of trucks each month		
Month	**Amount of trucks to use per month**	**Amount of 1 Ton trucks needed**	**Amount of 0.5 Ton trucks needed**
Mar	4.36	4	1
Apr	3.76	4	0
May	3.73	4	0
Jun	3.34	3	1
Jul	12.51	13	0
Aug	5.92	6	1
Sep	5.87	6	1
Oct	5.63	6	1
Nov	3.40	3	1
Dec	3.53	4	0
Jan	3.86	4	1
Feb	6.80	7	0
Mar	3.93	4	0

Table 33: Break even amount of trucks each month

15.2.2.5 Total amount of variable selling expense

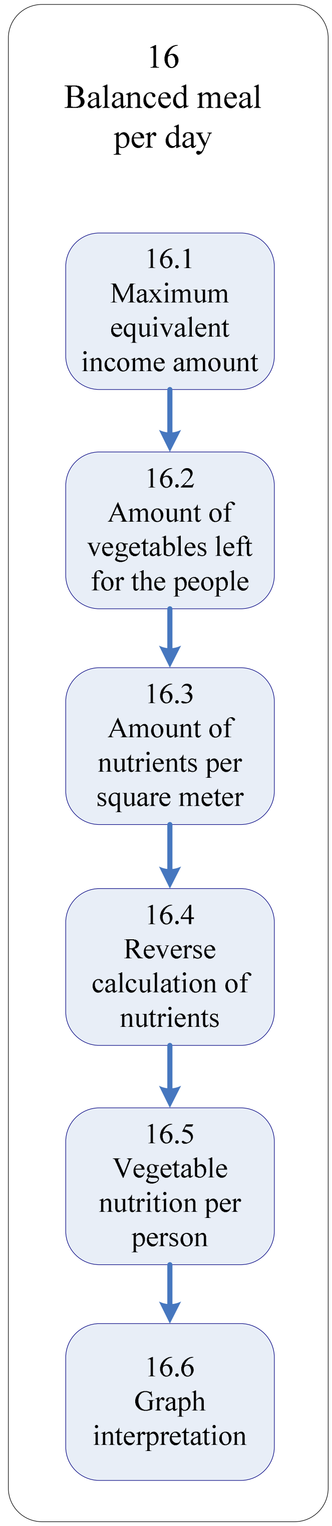
The amount of 1 ton and 0.5 ton trucks that need to be used can now be multiplied by the cost per truck trip for the different trucks as shown in section 15.2.2.1 shown in Table 28. 1 Ton trucks will be chosen first, until there is less than 0.5 Tons left to be delivered. The reason for this is that a 1 Ton truck trip is cheaper than two 0.5 Ton truck trips, but still the amount of expense that will be saved by using a 0.5 Ton truck, will only be counting as a bonus, instead of using a 1 Ton truck as explained in section 15.2.2.1. Table 34 shows the total amount of variable selling expenses per month. These variable selling expenses and the fixed expenses must be subtracted from the gross margin. This will be discussed in chapter 8.

	Variable expenses for delivering vegetables to the market		
Month	**1 Ton trucks needed**	**0.5 Ton trucks needed**	**Total variable expense**
2010			
March	4	1	1919.9587
April	4	0	1656.3204
May	4	0	1656.3204
June	3	1	1505.8786
July	13	0	5383.0413
August	6	1	2748.1189
September	6	1	2748.1189
October	6	1	2748.1189
November	3	1	1505.8786
December	4	0	1656.3204
2011			
January	4	1	1919.9587
February	7	0	2898.5607
March	4	0	1656.3204

Table 34: Variable expenses for delivering vegetables to the market

Chapter 8

Chapter 8 flow diagram



16 Balanced meals per day

16.1 Maximum equivalent income amount

Table 35 on the next page shows the equivalent income amount of the vegetables that is left for the people to eat after all necessary expenses have been deducted.

It is necessary to determine the percentage amount of expenses that was deducted from the total maximum profit. The reason for this is because the percentage of vegetables that was sold of each must be subtracted from the total amount of vegetables available for the month. An equal percentage of all the different types of vegetables will be sold, in order to keep the balanced area ratio constant. Table 36 shows the percentage amount of vegetables that is left each month for the people to eat. The percentages were calculated by dividing the 'Equivalent price amount left' by the 'Maximum relative profit'.

	Maximum vegetable price equivalent amount that is left for the people to use				
2010	**Maximum profit**	**Fixed expenses**	**Var. selling expenses**	**Total expenses after maximization**	**Equivalent price amount left**
Mar	R 352,598.83	R 13,666.67	R 1,919.96	R 15,586.63	R 337,012.21
Apr	R 366,338.45	R 13,666.67	R 1,656.32	R 15,322.99	R 351,015.46
May	R 367,839.83	R 13,666.67	R 1,656.32	R 15,322.99	R 352,516.85
Jun	R 68,915.50	R 13,666.67	R 1,505.88	R 15,172.55	R 53,742.96
Jul	R 149,227.16	R 13,666.67	R 5,383.04	R 19,049.71	R 130,177.45
Aug	R 109,833.72	R 13,666.67	R 2,748.12	R 16,414.79	R 93,418.93
Sep	R 110,276.31	R 13,666.67	R 2,748.12	R 16,414.79	R 93,861.52
Oct	R 260,118.05	R 13,666.67	R 2,748.12	R 16,414.79	R 243,703.26
Nov	R 379,580.87	R 13,666.67	R 1,505.88	R 15,172.55	R 364,408.33
Dec	R 364,371.70	R 13,666.67	R 1,656.32	R 15,322.99	R 349,048.71
2011					
Jan	R 81,135.77	R 13,666.67	R 1,919.96	R 15,586.63	R 65,549.15
Feb	R 77,560.58	R 13,666.67	R 2,898.56	R 16,565.23	R 60,995.36
Mar	R 370,007.56	R 13,666.67	R 1,656.32	R 15,322.99	R 354,684.57

Table 35: Maximum vegetable price equivalent amount that is left for the people to use

2010	Percentage of vegetables left to be divided between people	
Mar	0.9558	95.58%
Apr	0.9582	95.82%
May	0.9583	95.83%
Jun	0.7798	77.98%
Jul	0.8723	87.23%
Aug	0.8505	85.05%
Sep	0.8511	85.11%
Oct	0.9369	93.69%
Nov	0.9600	96.00%
Dec	0.9579	95.79%
2011		
Jan	0.8079	80.79%
Feb	0.7864	78.64%
Mar	0.9586	95.86%

Table 36: Percentage of vegetables left to be divided between people

16.2 Amount of vegetables left for the people

The amount of vegetables left for the people to eat can now be determined by multiplying the total amount of vegetables available after maximization with the percentage amount that is left. Table 37 shows the number of square meters that is left of each vegetable to feed the people after deductions were done:

16.3 Amount of nutrients per square meter

The amount of nutrients per square meter can now be determined by multiplying the square meter amounts that is left with the amount of nutrients per square meter each vegetable provides. Table 38 provides these amounts.

	Amount of square meters left for the people to eat												
	2010										2011		
Dark Green	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lettuce	3290	3299	3290	0	7763	3003	2928	0	3305	0	0	0	2707
Onions	0	0	0	0	0	0	0	2930	0	0	0	0	0
Cucumber	0	0	0	0	0	0	0	0	0	0	2781	0	0
Spinach	0	0	0	3299	0	0	0	0	0	0	0	0	0
Broccoli	0	0	0	0	0	0	0	0	0	0	0	0	0
Garden peas	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage	0	0	0	0	0	0	0	0	0	3298	0	2707	0
Red, Orange, Dark Yellow													
Tomatoes	0	2439	2432	0	1985	0	0	0	0	0	2056	2001	0
Carrots	0	0	0	0	0	0	0	0	0	0	0	0	0
Peppers	0	0	0	0	0	0	0	2166	2443	2438	0	0	0
Squash	0	0	0	0	0	0	0	0	0	0	0	0	0
Radish	0	0	0	2439	0	0	0	0	0	0	0	0	0
Beet	2432	0	0	0	0	2220	2165	0	0	0	0	0	2001
Starchy													
Butternut	0	0	0	0	0	0	0	0	0	0	5261	0	0
Sweet potatoes	0	0	0	0	0	0	0	5543	0	0	0	0	0
Potatoes	6225	6240	6225	0	0	0	0	0	6252	6239	0	0	5122
Corn	0	0	0	0	0	0	0	0	0	0	0	5122	0
Turnips	0	0	0	6241	0	5681	5539	0	0	0	0	0	0
Pumpkin	0	0	0	0	0	0	0	0	0	0	0	0	0
Total area left	11947	11977	11947	11979	9748	10904	10632	10639	12000	11974	10099	9830	9830

Table 37: Amount of square meters left for the people to eat

	Nutrient value per square meter	Amount of nutrients left to feed the people												
		2010										2011		
Dark Green		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lettuce	3137.76	10,324,262	10,349,944	10,324,262	0	24,359,383	9,422,848	9,187,418	0	10,369,988	0	0	0	8,494,738
Onions	3517.41	0	0	0	0	0	0	0	10,306,277	0	0	0	0	0
Cucumber	10368.46	0	0	0	0	0	0	0	0	0	0	28,836,520	0	0
Spinach	5405.71	0	0	0	17,833,954	0	0	0	0	0	0	0	0	0
Broccoli	5367.65	0	0	0	0	0	0	0	0	0	0	0	0	0
Garden peas	688.37	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage	10472.10	0	0	0	0	0	0	0	0	0	34,534,170	0	28,350,670	0
Red, Orange, Dark Yellow														
Tomatoes	5794.13	0	14,129,272	14,094,212	0	11,499,546	0	0	0	0	0	11,913,263	11,596,629	0
Carrots	7036.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Peppers	5247.93	0	0	0	0	0	0	0	11,367,917	12,822,109	12,794,311	0	0	0
Squash	3307.52	0	0	0	0	0	0	0	0	0	0	0	0	0
Radish	1614.03	0	0	0	3,936,597	0	0	0	0	0	0	0	0	0
Beet	3372.80	8,204,342	0	0	0	0	7,488,018	7,300,931	0	0	0	0	0	6,750,481
Starchy														
Butternut	2207.58	0	0	0	0	0	0	0	0	0	0	11,615,009	0	0
Sweet potatoes	58903.14	0	0	0	0	0	0	0	326,506,305	0	0	0	0	0
Potatoes	14253.30	88,721,306	88,942,003	88,721,306	0	0	0	0	0	89,114,246	88,921,046	0	0	72,999,329
Corn	3587.73	0	0	0	0	0	0	0	0	0	0	0	18,374,845	0
Turnips	3033.87	0	0	0	18,935,049	0	17,235,870	16,805,233	0	0	0	0	0	0
Pumpkin	2814.89	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 38: Amount of nutrients left to feed the people

16.4 Reverse calculation of nutrients

In the beginning the amount of nutrients per square meter were calculated, as can be seen in section 9.2.4. The amount of nutrients in 1 vegetable plant - as can be seen in section 9.1.3 - were multiplied by the amount of plants per square meter – as can be seen in section 9.2.2 – to determine the amount of nutrients in a square meter. The amount of nutrients in one vegetable plant was calculated as a percentage of the Recommended Daily Allowance, to determine how 'healthy' a certain plant is for people. All of the nutritional values that were used were according to this 'healthy' vegetable percentage. In order to recover the amount of nutrients that is available for use, it must be transformed back to the Recommended Daily Allowance grams. By taking the average amount of nutrients in a plant (the 'rating') and dividing it by the amount of the nutrient percentages as can be seen in Table 39, and then by the RDA grams. All of this must be done in order to recover these RDA grams. Table 39 shows these values.

	Nutrients per plant/Total percentage 'rating'/Total amount of RDA grams	Total nutrient grams in balance according to RDA												
		2010										2011		
Dark Green		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lettuce	0.1225	10873221	10900269	10873221	0	25654613	9923877	9675929	0	10921378	0	0	0	8946418
Onions	0.1638	0	0	0	0	0	0	0	9682753	0	0	0	0	0
Cucumber	2.7283	0	0	0	0	0	0	0	0	0	0	9190691	0	0
Spinach	0.0668	0	0	0	10902210	0	0	0	0	0	0	0	0	0
Broccoli	0.5414	0	0	0	0	0	0	0	0	0	0	0	0	0
Garden peas	0.0160	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage	0.9054	0	0	0	0	0	0	0	0	0	10897701	0	8946418	0
Red, Orange, Dark Yellow														
Tomatoes	0.5656	0	8058442	8038446	0	6558612	0	0	0	0	0	6794570	6613982	0
Carrots	0.0106	0	0	0	0	0	0	0	0	0	0	0	0	0
Peppers	0.4235	0	0	0	0	0	0	0	7158345	8074046	8056542	0	0	0
Squash	0.7414	0	0	0	0	0	0	0	0	0	0	0	0	0
Radish	0.0049	0	0	0	8059877	0	0	0	0	0	0	0	0	0
Beet	0.0393	8038447	0	0	0	0	7336607	7153303	0	0	0	0	0	6613983
Starchy														
Butternut	0.6680	0	0	0	0	0	0	0	0	0	0	17386891	0	0
Sweet potatoes	1.7825	0	0	0	0	0	0	0	18317772	0	0	0	0	0
Potatoes	0.4313	20569893	20621062	20569893	0	0	0	0	0	20660996	20616203	0	0	16924778
Corn	0.1551	0	0	0	0	0	0	0	0	0	0	0	16924776	0
Turnips	0.0306	0	0	0	20624738	0	18773931	18304865	0	0	0	0	0	0
Pumpkin	1.0021	0	0	0	0	0	0	0	0	0	0	0	0	0
		39481562	39579773	39481561	39586825	32213226	36034415	35134097	35158871	39656420	39570446	33372153	32485176	32485179

Table 39: Total nutrient grams in balance according to RDA

16.5 Vegetable nutrition per person

The people of Nellmapius need to have a balanced diet, with all the necessary amount of nutrients. The Recommended Daily Allowance was determined in Chapter 3, and these people need to be fed in accordance to this RDA. The RDA amount of nutrients per person per day is 3304.60g. This value is an accumulation of all the necessary nutrients a person needs to take in. The amount of nutrients in each vegetable were compared to the amount Recommended Daily Allowance, in order to balance all of the nutrients with each other. The amount of nutrients a person needs per month can just be multiplied by 30 (average amount of days in a month). This RDA nutrient amount is 99138.15g nutrients/month. In the beginning all of the vegetables were compared to the RDA, and a percentage rating of importance were calculated. These values were used throughout this whole project. This amount of nutrients that is left to feed the people was converted back to the original grams, as can be seen in Table 39.

For the final answer of this project, the amount of nutrients that is left to feed the people can be divided by the RDA grams of nutrients needed each day for a month. By doing this calculation the amount of people that can have a balanced meal each day can be determined. This amount of people can be fed, while the vegetable farm is self sustainable. Table 40 and Graph 1 shows the amount of people that can have a balanced meal each day.

2010	Number of people that can have a balanced meal each day according to each month
March	398
April	399
May	398
June	399
July	324
August	362
September	354
October	355
November	400
2011	
December	399
January	337
February	325

Table 40: The amount of people that can have a balanced meal each day

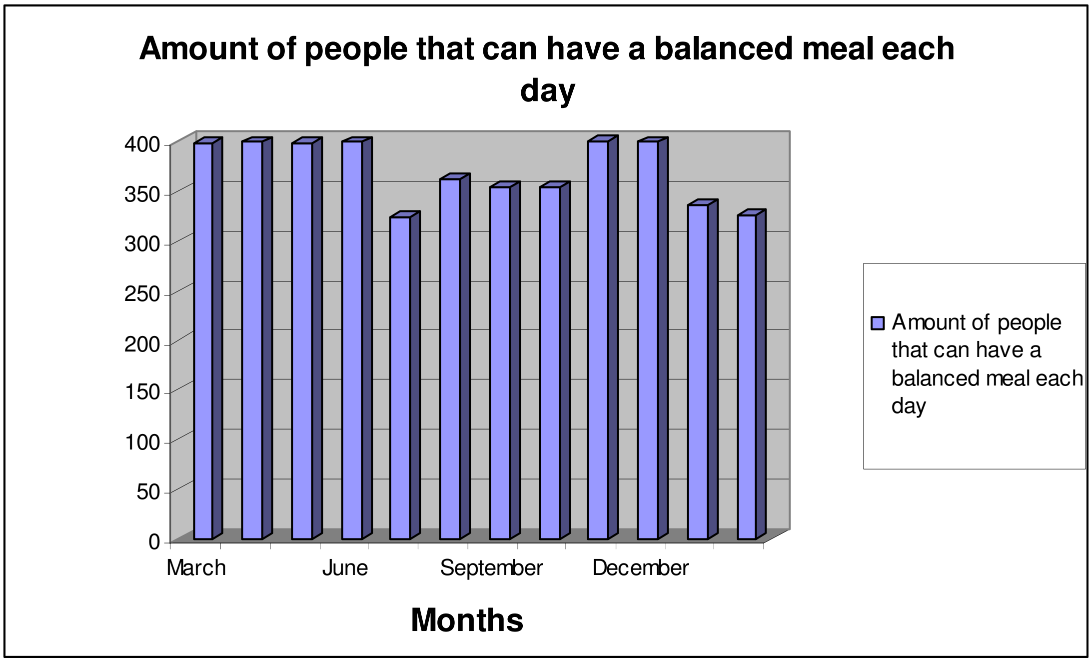


Figure 8: The number of people that can have a balanced meal each day, while ensuring self sustainability

16.6 Graph interpretation

The graph shows the number of people that can have a balanced meal each day according to each month. By feeding this amount of people each month, the farm of 5 hectares can be self sustainable. The reason for the different amount of people each month is the following. When the vegetables are sold, a certain amount of trucks are needed to deliver the vegetables to the market. For the month of March 2010, 4.49 Tons of vegetables need ne be delivered. A 4.49 ton truck does not exist, therefore four 1 Ton trucks, and one 0.5 Ton truck will be used, which leaves 10 kilogram of unused space. This amount of unused space needs to be paid for each month, and the amount of unused space each month will differ. That is the reason why the amount of people that can have a balanced meal each month will differ for each month.

17 Conclusion

The answer that I want out of this project is for the project to tell me how much, and when to plant certain vegetables, in order to have the maximum amount of financial benefit, to create self sustainability.

Different tools and techniques were used in order to successfully complete this project. Starting with a formulation in Excel to determine the amount of nutrients each vegetable provides given the amount of space it takes up in the area provided. The next step was the maximization of the amount of profit that can be generated by planting the correct amounts of vegetables. All of the expenses were considered, from planting to selling vegetables while determining the amount of OVC that can have a balanced meal each on a daily basis. This part was done by a mathematical formulation using linear programming. The aim of the project is also to create jobs and help rural communities build up their own community and be able to help themselves.

By concluding this project a detailed schedule per month were created. The people at Nellmapius will exactly know when the vegetables must be planted and harvested as well as the amount. The amounts of people that can have a balanced meal each day according to the month of harvest were determined. The amount of land Heartbeat has won't be sufficient to feed all of the OVC, the amount of land Nellmapius needs to feed their OVC can now be determined for each month. The amount of land that must be available to feed 4500 OVC in March 2010 will be more or less 56.53 hectares.

Agriculture is an every changing industry, and the uncontrollable factors are plenty. Therefore a global optimal solution in agriculture will never be found, but a sufficient representative model will give a usable answer. The answer to this document can be used to develop sustainable communities.

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Appendix A:

Recommended Daily Allowance

recommended types of nutrients to be taken daily	Recommended 100% daily allowance in grams(On average between men and women) **Milligrams/day**	Recommended 100% daily allowance in grams(On average between men and women) **grams/day**
Minerals		
Calcium	1000	1
Iron (Fe)	18	0.018
Magnesium (Mg)	355	0.355
Phosphorus	700	0.7
Potassium (K)	4700	4.7
Sodium	1500	1.5
Zinc (Zn)	9.5	0.0095
Vitamins		
Vitamin C/Ascorbic Acid	82.5	0.0825
Thiamin/Vitamin B1	1.15	0.00115
Riboflavin/Vitamin B2	1.2	0.0012
Niacin/Vitamin B3	15	0.015
Pantothenic Acid	5	0.005
Vitamin B6	1.3	0.0013
Vitamin B12	0.0024	0.0000024
Folate/Folic acid	0.4	0.0004
Vitamin A (IU)/Retinol	0.8	0.0008
Vitamin E	15	0.015
Selenium	0.055	0.000055
Macronutrients		
Water	3000000	3000
Protein	56000	56
Carbohydrates	130000	130
Fiber	25000	25
Total fat	65000	65
Saturated fat	20000	20
Cholesterol	200	0.2

Appendix B:

Nutritional Information

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 132g (1cup) of butternut (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2500g) plant of butternut (in grams,raw or cooked in water)
Minerals		
Calcium	0.025	0.473484848
Iron (Fe)	0.00077	0.014583333
Magnesium (Mg)	0.012	0.227272727
Phosphorus	0.03828	0.725
Potassium (K)	0.176	3.333333333
Sodium	0.003	0.056818182
Zinc (Zn)	0.00016	0.003030303
Vitamins		
Vitamin C/Ascorbic Acid	0.005	0.09469697
Thiamin/Vitamin B1	0.00007	0.001325758
Riboflavin/Vitamin B2	0.00005	0.00094697
Niacin/Vitamin B3	0.00061	0.01155303
Pantothenic Acid	0.000226533	0.004290393
Vitamin B6	0.00009	0.001704545
Vitamin B12	0	0
Folate/Folic acid	0.000022	0.000416667
Vitamin A (IU)/Retinol	0	0
Vitamin E	0	0
Selenium	0.000006	0.000113636
Macronutrients		
Water	116	2196.969697
Protein	2	37.87878788
Carbohydrates	13	246.2121212
Fiber	2	37.87878788
Total fat	0.99	18.75
Saturated fat	0.02	0.378787879
Cholesterol	0.04	0.757575758
		2543.774328
		2543.774328

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 166g (1cup) of sweet potato (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2130g) plant of sweet potato (in grams, raw or cooked in water)
Minerals		
Calcium	0.045	0.726136364
Iron (Fe)	0.0012	0.019363636
Magnesium (Mg)	0.03	0.484090909
Phosphorus	0.078631579	1.268827751
Potassium (K)	0.382	6.164090909
Sodium	0.045	0.726136364
Zinc (Zn)	0.00033	0.005325
Vitamins		
Vitamin C/Ascorbic Acid	0.021	0.338863636
Thiamin/Vitamin B1	0.00009	0.001452273
Riboflavin/Vitamin B2	0.00008	0.001290909
Niacin/Vitamin B3	0.00089	0.014361364
Pantothenic Acid	0.001328	0.021429091
Vitamin B6	0.00027	0.004356818
Vitamin B12	0	0
Folate/Folic acid	0.00001	0.000161364
Vitamin A (IU)/Retinol	0.00131	0.021138636
Vitamin E	0.00156	0.025172727
Selenium	0.0000009	1.45227E-05
Macronutrients		
Water	133	2146.136364
Protein	2	32.27272727
Carbohydrates	29	467.9545455
Fiber	4	64.54545455
Total fat	0.99	15.975
Saturated fat	0.05	0.806818182
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 150g (1cup) of potato (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (1000g) plant of potato (in grams, raw or cooked in water)
Minerals		
Calcium	0.013	0.098484848
Iron (Fe)	0.00127	0.009621212
Magnesium (Mg)	0.034	0.257575758
Phosphorus	0.091549296	0.693555271
Potassium (K)	0.572	4.333333333
Sodium	0.007	0.053030303
Zinc (Zn)	0.00047	0.003560606
Vitamins		
Vitamin C/Ascorbic Acid	0.018	0.136363636
Thiamin/Vitamin B1	0.00015	0.001136364
Riboflavin/Vitamin B2	0.00003	0.000227273
Niacin/Vitamin B3	0.00213	0.016136364
Pantothenic Acid	0.00041831	0.003169014
Vitamin B6	0.00044	0.003333333
Vitamin B12	0	0
Folate/Folic acid	0.000015	0.000113636
Vitamin A (IU)/Retinol	0	0
Vitamin E	0	0
Selenium	0	0
Macronutrients		
Water	116	878.7878788
Protein	3	22.72727273
Carbohydrates	30	227.2727273
Fiber	2	15.15151515
Total fat	0.99	7.5
Saturated fat	0.04	0.303030303
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 55g (1cup) of lettuce (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (355g) plant of lettuce (in grams, raw or cooked in water)
Minerals		
Calcium	0.019	0.122636364
Iron (Fe)	0.00069	0.004453636
Magnesium (Mg)	0.007	0.045181818
Phosphorus	0.018	0.116181818
Potassium (K)	0.132	0.852
Sodium	0.003	0.019363636
Zinc (Zn)	0.00011	0.00071
Vitamins		
Vitamin C/Ascorbic Acid	0.002	0.012909091
Thiamin/Vitamin B1	0.00003	0.000193636
Riboflavin/Vitamin B2	0.00003	0.000193636
Niacin/Vitamin B3	0.0002	0.001290909
Pantothenic Acid	0.000083	0.000535727
Vitamin B6	0.00005	0.000322727
Vitamin B12	0	0
Folate/Folic acid	0.00004	0.000258182
Vitamin A (IU)/Retinol	0.000092	0.000593818
Vitamin E	0.0001	0.000645455
Selenium	0.00000099	0.00000639
Macronutrients		
Water	53	342.0909091
Protein	1	6.454545455
Carbohydrates	1	6.454545455
Fiber	1	6.454545455
Total fat	0.99	6.39
Saturated fat	0.02	0.129090909
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 123g (1cup) of tomato (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2581g) plant of tomato (in grams, raw or cooked in water)
Minerals		
Calcium	0.0123	0.2581
Iron (Fe)	0.00033	0.006924634
Magnesium (Mg)	0.01352	0.283700163
Phosphorus	0.03321	0.69687
Potassium (K)	0.29151	6.11697
Sodium	0.00615	0.12905
Zinc (Zn)	0.0002	0.004196748
Vitamins		
Vitamin C/Ascorbic Acid	0.01562	0.327766016
Thiamin/Vitamin B1	0.00004	0.00083935
Riboflavin/Vitamin B2	0.00002	0.000419675
Niacin/Vitamin B3	0.00073	0.01531813
Pantothenic Acid	0.000109333	0.002294222
Vitamin B6	0.00009	0.001888537
Vitamin B12	0	0
Folate/Folic acid	0.00001845	0.00038715
Vitamin A (IU)/Retinol	0.00007626	0.00160022
Vitamin E	0.00066	0.013849268
Selenium	0	0
Macronutrients		
Water	0.11	2.308211382
Protein	1.08	22.66243902
Carbohydrates	4.82	101.141626
Fiber	1.47	30.84609756
Total fat	0.24	5.036097561
Saturated fat	0.05	1.049186992
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 80g (1cup) of onion (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average plant (769g) of Onions (in grams, raw or cooked in water)
Minerals		
Calcium	0.018	0.173025
Iron (Fe)	0.00015	0.001441875
Magnesium (Mg)	0.008	0.0769
Phosphorus	0.021052632	0.202368421
Potassium (K)	0.115	1.1054375
Sodium	0.002	0.019225
Zinc (Zn)	0.00013	0.001249625
Vitamins		0
Vitamin C/Ascorbic Acid	0.005	0.0480625
Thiamin/Vitamin B1	0.00004	0.0003845
Riboflavin/Vitamin B2	0.00002	0.00019225
Niacin/Vitamin B3	0.00007	0.000672875
Pantothenic Acid	9.68421E-05	0.000930895
Vitamin B6	0.00012	0.0011535
Vitamin B12	0	0
Folate/Folic acid	0.000015	0.000144188
Vitamin A (IU)/Retinol	0	0
Vitamin E	0.00002	0.00019225
Selenium	0.00000099	9.51638E-06
Macronutrients		0
Water	71	682.4875
Protein	1	9.6125
Carbohydrates	8	76.9
Fiber	1	9.6125
Total fat	0.99	9.516375
Saturated fat	0.02	0.19225
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 75g (1cup) of cucumber (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average plant (4348g) of cucumber (in grams, raw or cooked in water)
Minerals		
Calcium	0.012	0.69568
Iron (Fe)	0.021	1.21744
Magnesium (Mg)	0.01	0.579733333
Phosphorus	0.017307692	1.003384615
Potassium (K)	0.111	6.43504
Sodium	0.002	0.115946667
Zinc (Zn)	0.00015	0.008696
Vitamins		
Vitamin C/Ascorbic Acid	0.002	0.115946667
Thiamin/Vitamin B1	0.00002	0.001159467
Riboflavin/Vitamin B2	0.00002	0.001159467
Niacin/Vitamin B3	0.00007	0.004058133
Pantothenic Acid	0.000194712	0.011288077
Vitamin B6	0.00003	0.0017392
Vitamin B12	0	0
Folate/Folic acid	0.000005	0.000289867
Vitamin A (IU)/Retinol	0.000004	0.000231893
Vitamin E	0.00002	0.001159467
Selenium	0.00000099	5.73936E-05
Macronutrients		
Water	72	4174.08
Protein	0.99	57.3936
Carbohydrates	3	173.92
Fiber	0.99	57.3936
Total fat	0.99	57.3936
Saturated fat	0.03	1.7392
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 61g (1cup) of carrot (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average plant (19g) of carrot (in grams, raw or cooked in water)
Minerals		
Calcium	0.02	0.006229508
Iron (Fe)	0.00018	5.60656E-05
Magnesium (Mg)	0.007	0.002180328
Phosphorus	0.02196	0.00684
Potassium (K)	0.195	0.060737705
Sodium	0.042	0.013081967
Zinc (Zn)	0.00015	4.67213E-05
Vitamins		
Vitamin C/Ascorbic Acid	0.004	0.001245902
Thiamin/Vitamin B1	0.00004	1.2459E-05
Riboflavin/Vitamin B2	0.00004	1.2459E-05
Niacin/Vitamin B3	0.0006	0.000186885
Pantothenic Acid	0.0001665	5.18607E-05
Vitamin B6	0.00008	2.4918E-05
Vitamin B12	0	0
Folate/Folic acid	0.000012	3.7377E-06
Vitamin A (IU)/Retinol	0.000367	0.000114311
Vitamin E	0.0004	0.00012459
Selenium	0.00000099	3.08361E-07
Macronutrients		
Water	54	16.81967213
Protein	1	0.31147541
Carbohydrates	6	1.868852459
Fiber	2	0.62295082
Total fat	0.99	0.308360656
Saturated fat	0.02	0.006229508
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 30g (1cup) of spinach (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average plant (71g) of spinach (in grams, raw or cooked in water)
Minerals		
Calcium	0.03	0.071
Iron (Fe)	0.00081	0.001917
Magnesium (Mg)	0.024	0.0568
Phosphorus	0.015	0.0355
Potassium (K)	0.167	0.395233333
Sodium	0.024	0.0568
Zinc (Zn)	0.00016	0.000378667
Vitamins		
Vitamin C/Ascorbic Acid	0.008	0.018933333
Thiamin/Vitamin B1	0.00002	4.73333E-05
Riboflavin/Vitamin B2	0.00006	0.000142
Niacin/Vitamin B3	0.00022	0.000520667
Pantothenic Acid	0.00002	4.73333E-05
Vitamin B6	0.00006	0.000142
Vitamin B12	0	0
Folate/Folic acid	0.000058	0.000137267
Vitamin A (IU)/Retinol	0.000141	0.0003337
Vitamin E	0.00061	0.001443667
Selenium	0.00000099	0.000002343
Macronutrients		
Water	27	63.9
Protein	1	2.366666667
Carbohydrates	1	2.366666667
Fiber	1	2.366666667
Total fat	0.99	2.343
Saturated fat	0.02	0.047333333
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 44g (1cup) of broccoli (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (383g) plant of broccoli (in grams, raw or cooked in water)
Minerals		
Calcium	0.021	0.182795455
Iron (Fe)	0.00032	0.002785455
Magnesium (Mg)	0.009	0.078340909
Phosphorus	0.029010989	0.252527473
Potassium (K)	0.139	1.209931818
Sodium	0.015	0.130568182
Zinc (Zn)	0.00018	0.001566818
Vitamins		
Vitamin C/Ascorbic Acid	0.039	0.339477273
Thiamin/Vitamin B1	0.00003	0.000261136
Riboflavin/Vitamin B2	0.00005	0.000435227
Niacin/Vitamin B3	0.00028	0.002437273
Pantothenic Acid	0.000251912	0.00219278
Vitamin B6	0.00008	0.000696364
Vitamin B12	0	0
Folate/Folic acid	0.00028	0.002437273
Vitamin A (IU)/Retinol	0.00015	0.001305682
Vitamin E	0.00034	0.002959545
Selenium	0.000001	8.70455E-06
Macronutrients		
Water	39	339.4772727
Protein	1	8.704545455
Carbohydrates	3	26.11363636
Fiber	1	8.704545455
Total fat	0.99	8.6175
Saturated fat	0.02	0.174090909
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 100g (2items) of beet (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (125g) plant of beet (in grams,raw or cooked in water)
Minerals		
Calcium	0.016	0.02
Iron (Fe)	0.00079	0.0009875
Magnesium (Mg)	0.023	0.02875
Phosphorus	0.055	0.06875
Potassium (K)	0.305	0.38125
Sodium	0.077	0.09625
Zinc (Zn)	0.00035	0.0004375
Vitamins		
Vitamin C/Ascorbic Acid	0.004	0.005
Thiamin/Vitamin B1	0.00003	0.0000375
Riboflavin/Vitamin B2	0.00004	0.00005
Niacin/Vitamin B3	0.00033	0.0004125
Pantothenic Acid	0.000155	0.00019375
Vitamin B6	0.00007	0.0000875
Vitamin B12	0	0
Folate/Folic acid	0.000082	0.0001025
Vitamin A (IU)/Retinol	0.000002	0.0000025
Vitamin E	0.00004	0.00005
Selenium	0.000001	0.00000125
Macronutrients		
Water	87	108.75
Protein	2	2.5
Carbohydrates	10	12.5
Fiber	2	2.5
Total fat	0.99	1.2375
Saturated fat	0.03	0.0375
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 70g (1cup) of cabbage (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2000g) plant of cabbage (in grams, raw or cooked in water)
Minerals		
Calcium	0.033	0.942857143
Iron (Fe)	0.00041	0.011714286
Magnesium (Mg)	0.011	0.314285714
Phosphorus	0.0238	0.68
Potassium (K)	0.172	4.914285714
Sodium	0.013	0.371428571
Zinc (Zn)	0.00013	0.003714286
Vitamins		
Vitamin C/Ascorbic Acid	0.023	0.657142857
Thiamin/Vitamin B1	0.00004	0.001142857
Riboflavin/Vitamin B2	0.00003	0.000857143
Niacin/Vitamin B3	0.00021	0.006
Pantothenic Acid	0.000098	0.0028
Vitamin B6	0.00007	0.002
Vitamin B12	0	0
Folate/Folic acid	0.00003	0.000857143
Vitamin A (IU)/Retinol	0.000006	0.000171429
Vitamin E	0.0001	0.002857143
Selenium	0.000001	2.85714E-05
Macronutrients		
Water	65	1857.142857
Protein	1	28.57142857
Carbohydrates	4	114.2857143
Fiber	2	57.14285714
Total fat	0.099	2.828571429
Saturated fat	0.01	0.285714286
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 85g (1/2cup) of garden peas (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (31g) plant of garden peas (in grams, raw or cooked in water)
Minerals		
Calcium	0.017	0.0062
Iron (Fe)	0.00081	0.000295412
Magnesium (Mg)	0.014	0.005105882
Phosphorus	0.0935	0.0341
Potassium (K)	0.147	0.053611765
Sodium	0.214	0.078047059
Zinc (Zn)	0.0006	0.000218824
Vitamins		
Vitamin C/Ascorbic Acid	0.008	0.002917647
Thiamin/Vitamin B1	0.0001	3.64706E-05
Riboflavin/Vitamin B2	0.00007	2.55294E-05
Niacin/Vitamin B3	0.00062	0.000226118
Pantothenic Acid	0.0000885	3.22765E-05
Vitamin B6	0.00005	1.82353E-05
Vitamin B12	0	0
Folate/Folic acid	0.000037	1.34941E-05
Vitamin A (IU)/Retinol	0.000023	8.38824E-06
Vitamin E	0.00003	1.09412E-05
Selenium	0.000001	3.64706E-07
Macronutrients		
Water	69	25.16470588
Protein	4	1.458823529
Carbohydrates	11	4.011764706
Fiber	3	1.094117647
Total fat	0.99	0.361058824
Saturated fat	0.05	0.018235294
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 75g (1/2cup) of peppers (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (800g) plant of peppers (in grams, raw or cooked in water)
Minerals		
Calcium	0.006	0.064
Iron (Fe)	0.00031	0.003306667
Magnesium (Mg)	0.007	0.074666667
Phosphorus	0.0165	0.176
Potassium (K)	0.113	1.205333333
Sodium	0.001	0.010666667
Zinc (Zn)	0.00008	0.000853333
Vitamins		
Vitamin C/Ascorbic Acid	0.051	0.544
Thiamin/Vitamin B1	0.00004	0.000426667
Riboflavin/Vitamin B2	0.00002	0.000213333
Niacin/Vitamin B3	0.00032	0.003413333
Pantothenic Acid	0.000074	0.000789333
Vitamin B6	0.00016	0.001706667
Vitamin B12	0	0
Folate/Folic acid	0.000011	0.000117333
Vitamin A (IU)/Retinol	0.00001	0.000106667
Vitamin E	0.00036	0.00384
Selenium	0.00000099	0.00001056
Macronutrients		
Water	70	746.6666667
Protein	1	10.66666667
Carbohydrates	3	32
Fiber	1	10.66666667
Total fat	0.99	10.56
Saturated fat	0.04	0.426666667
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 123g (1/2cup) of pumpkin (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (2941g) plant of pumpkin (in grams, raw or cooked in water)
Minerals		
Calcium	0.018	0.430390244
Iron (Fe)	0.0007	0.016737398
Magnesium (Mg)	0.011	0.26301626
Phosphorus	0.02583	0.61761
Potassium (K)	0.282	6.742780488
Sodium	0.001	0.023910569
Zinc (Zn)	0.00028	0.006694959
Vitamins		
Vitamin C/Ascorbic Acid	0.006	0.143463415
Thiamin/Vitamin B1	0.00004	0.000956423
Riboflavin/Vitamin B2	0.0001	0.002391057
Niacin/Vitamin B3	0.00051	0.01219439
Pantothenic Acid	0.0003669	0.008772788
Vitamin B6	0.00005	0.001195528
Vitamin B12	0	0
Folate/Folic acid	0.000011	0.000263016
Vitamin A (IU)/Retinol	0.000306	0.007316634
Vitamin E	0.00098	0.023432358
Selenium	0.00000099	2.36715E-05
Macronutrients		
Water	115	2749.715447
Protein	1	23.91056911
Carbohydrates	6	143.4634146
Fiber	1	23.91056911
Total fat	0.99	23.67146341
Saturated fat	0.05	1.195528455
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 103g (1/2cup) of squash (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (1667g) plant of squash (in grams, raw or cooked in water)
Minerals		
Calcium	0.023	0.372242718
Iron (Fe)	0.00045	0.00728301
Magnesium (Mg)	0.013	0.210398058
Phosphorus	0.03914	0.63346
Potassium (K)	0.448	7.250640777
Sodium	0.001	0.016184466
Zinc (Zn)	0.00023	0.003722427
Vitamins		0
Vitamin C/Ascorbic Acid	0.01	0.16184466
Thiamin/Vitamin B1	0.00002	0.000323689
Riboflavin/Vitamin B2	0.00007	0.001132913
Niacin/Vitamin B3	0.00051	0.008254078
Pantothenic Acid	0.0001936	0.003133313
Vitamin B6	0.00017	0.002751359
Vitamin B12	0	0
Folate/Folic acid	0.000021	0.000339874
Vitamin A (IU)/Retinol	0.000268	0.004337437
Vitamin E	0.00012	0.001942136
Selenium	0.00000099	1.60226E-05
Macronutrients		0
Water	91	1472.786408
Protein	1	16.18446602
Carbohydrates	9	145.6601942
Fiber	3	48.55339806
Total fat	0.99	16.02262136
Saturated fat	0.13	2.103980583
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 27g (6items) of radish (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (10g) plant of radish (in grams, raw or cooked in water)
Minerals		
Calcium	0.007	0.002592593
Iron (Fe)	0.00009	3.33333E-05
Magnesium (Mg)	0.003	0.001111111
Phosphorus	0.00648	0.0024
Potassium (K)	0.063	0.023333333
Sodium	0.011	0.004074074
Zinc (Zn)	0.00008	2.96296E-05
Vitamins		0
Vitamin C/Ascorbic Acid	0.004	0.001481481
Thiamin/Vitamin B1	0	0
Riboflavin/Vitamin B2	0.00001	3.7037E-06
Niacin/Vitamin B3	0.00007	2.59259E-05
Pantothenic Acid	0.00004446	1.64667E-05
Vitamin B6	0.00002	7.40741E-06
Vitamin B12	0	0
Folate/Folic acid	0.000007	2.59259E-06
Vitamin A (IU)/Retinol	0	0
Vitamin E	0	0
Selenium	0.00000099	3.66667E-07
Macronutrients		0
Water	26	9.62962963
Protein	0.99	0.366666667
Carbohydrates	1	0.37037037
Fiber	0.99	0.366666667
Total fat	0.099	0.036666667
Saturated fat	0.01	0.003703704
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 100g (1item) of corn (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (321g) plant of corn (in grams, raw or cooked in water)
Minerals		
Calcium	0.00212	0.0068052
Iron (Fe)	0.0006	0.001926
Magnesium (Mg)	0.03181	0.1021101
Phosphorus	0.125	0.40125
Potassium (K)	0.24759	0.7947639
Sodium	0.24245	0.7782645
Zinc (Zn)	0.00047	0.0015087
Vitamins		
Vitamin C/Ascorbic Acid	0.00616	0.0197736
Thiamin/Vitamin B1	0.00021	0.0006741
Riboflavin/Vitamin B2	0.00007	0.0002247
Niacin/Vitamin B3	0.0016	0.005136
Pantothenic Acid	0.00072	0.0023112
Vitamin B6	0.00005	0.0001605
Vitamin B12	0	0
Folate/Folic acid	0	0
Vitamin A (IU)/Retinol	0.00002187	7.02027E-05
Vitamin E	0.00009	0.0002889
Selenium	0	0
Macronutrients		
Water	0.06	0.1926
Protein	3.3	10.593
Carbohydrates	24.96	80.1216
Fiber	2.78	8.9238
Total fat	1.27	4.0767
Saturated fat	0.19	0.6099
Cholesterol	0	0

recommended types of nutrients to be taken daily	Amount of Min/Vit/Nutr. In 78g (1/2cup) of turnips (in grams)	Amount (in grams)of Min/Vit/Nutr. In an average sized (108g) plant of turnips (in grams, raw or cooked in water)
Minerals		
Calcium	0.026	0.036
Iron (Fe)	0.00014	0.000193846
Magnesium (Mg)	0.007	0.009692308
Phosphorus	0.02106	0.02916
Potassium (K)	0.138	0.191076923
Sodium	0.012	0.016615385
Zinc (Zn)	0.00009	0.000124615
Vitamins		
Vitamin C/Ascorbic Acid	0.009	0.012461538
Thiamin/Vitamin B1	0.00002	2.76923E-05
Riboflavin/Vitamin B2	0.00002	2.76923E-05
Niacin/Vitamin B3	0.00023	0.000318462
Pantothenic Acid	0.000156	0.000216
Vitamin B6	0.00005	6.92308E-05
Vitamin B12	0	0
Folate/Folic acid	0.000007	9.69231E-06
Vitamin A (IU)/Retinol	0	0
Vitamin E	0.00002	2.76923E-05
Selenium	0.00000099	1.37077E-06
Macronutrients		
Water	73	101.0769231
Protein	1	1.384615385
Carbohydrates	4	5.538461538
Fiber	2	2.769230769
Total fat	0.099	0.137076923
Saturated fat	0.01	0.013846154
Cholesterol	0	0

Average yield of butternut per square meter (kg/square meter)	2.5
Average yield of butternut per hectare (ton/ha.)	25
Average yield of butternut per hectare (kg/ha.)	25000

Average amount of plants per square meter	1
Average amount of plants per hectare	10000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of butternut (kilogram)	2.5
Average weight of 1 plant of butternut (gram)	2500

Amount of nutritional benefit a square meter of butternut will deliver	total	2207.583583
	average	88.30334334

Average yield of sweet potato per square meter (kg/square meter)	21.3
Average yield of sweet potato per hectare (ton/ha.)	213
Average yield of sweet potato per hectare (kg/ha.)	213000

Average amount of plants per square meter	10
Average amount of plants per hectare	90000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of Sweet potatoes (kilogram)	2.13
Average weight of 1 plant of Sweet potatoes (gram)	2130

Amount of nutritional benefit a square meter of sweet potato will deliver	58903.14188	total
	2356.125675	average

Average yield of potato per square meter (kg/square meter)	10
Average yield of potato per hectare (ton/ha.)	100
Average yield of potato per hectare (kg/ha.)	100000

Average amount of plants per square meter	10
Average amount of plants per hectare	100000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of potatoes (kilogram)	1
Average weight of 1 plant of potatoes (gram)	1000

Amount of nutritional benefit a square meter of potato will deliver	14253.29997
	570.131999

Average yield of lettuce per square meter (kg/square meter)	2.75
Average yield of lettuce per hectare (ton/ha.)	27.5
Average yield of lettuce per hectare (kg/ha.)	27500

Average amount of plants per square meter	7.75
Average amount of plants per hectare	77500
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of lettuce (kilogram)	0.35483871
Average weight of 1 plant of lettuce (gram)	354.8387097

Amount of nutritional benefit a square meter of lettuce will deliver	3137.76455
	130.7401896

Average yield of tomato per square meter (kg/square meter)	8
Average yield of tomato per hectare (ton/ha.)	80
Average yield of tomato per hectare (kg/ha.)	80000

Average amount of plants per square meter	3.1
Average amount of plants per hectare	31000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of tomato (kilogram)	2.580645161
Average weight of 1 plant of tomato (gram)	2580.645161

Amount of nutritional benefit a square meter of tomato will deliver	5794.130283
	241.4220951

Average yield of onion per square meter (kg/square meter)	5
Average yield of onion per hectare (ton/ha.)	50
Average yield of onion per hectare (kg/ha.)	50000

Average amount of plants per square meter	6.5
Average amount of plants per hectare	65000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of onions (kilogram)	0.769230769
Average weight of 1 plant of onions (gram)	769.2307692

Amount of nutritional benefit a square meter of onion will deliver	3517.406031
	140.6962413

Average yield of cucumber per square meter (kg/square meter)	5
Average yield of cucumber per hectare (ton/ha.)	50
Average yield of cucumber per hectare (kg/ha.)	50000

Average amount of plants per square meter	1.15
Average amount of plants per hectare	11500
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of onions (kilogram)	4.347826087
Average weight of 1 plant of onions (gram)	4347.826087

Amount of nutritional benefit a square meter of cucumber will deliver	10368.45921
	414.7383685

Average yield of carrot per square meter (kg/square meter)	3.75
Average yield of carrot per hectare (ton/ha.)	37.5
Average yield of carrot per hectare (kg/ha.)	37500

Average amount of plants per square meter	200
Average amount of plants per hectare	2000000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of onions (kilogram)	0.01875
Average weight of 1 plant of onions (gram)	18.75

Amount of nutritional benefit a square meter of carrot will deliver	7036.019267
	281.4407707

Average yield of spinach per square meter (kg/square meter)	1.75
Average yield of spinach per hectare (ton/ha.)	17.5
Average yield of spinach per hectare (kg/ha.)	17500

Average amount of plants per square meter	24.5
Average amount of plants per hectare	245000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of onions (kilogram)	0.071428571
Average weight of 1 plant of onions (gram)	71.42857143

Amount of nutritional benefit a square meter of spinach will deliver	5405.70862
	216.2283448

Average yield of broccoli per square meter (kg/square meter)	1.15
Average yield of broccoli per hectare (ton/ha.)	11.5
Average yield of broccoli per hectare (kg/ha.)	11500

Average amount of plants per square meter	3
Average amount of plants per hectare	30000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of broccoli (kilogram)	0.383333333
Average weight of 1 plant of broccoli (gram)	383

Amount of nutritional benefit a square meter of broccoli will deliver	5367.647354
	214.7058941

Average yield of beet per square meter (kg/square meter)	3.25
Average yield of beet per hectare (ton/ha.)	32.5
Average yield of beet per hectare (kg/ha.)	32500

Average amount of plants per square meter	26
Average amount of plants per hectare	260000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of beet (kilogram)	0.125
Average weight of 1 plant of beet (gram)	125

Amount of nutritional benefit a square meter of beet will deliver	3372.804547
	134.9121819

Average yield of cabbage per square meter (kg/square meter)	7
Average yield of cabbage per hectare (ton/ha.)	70
Average yield of cabbage per hectare (kg/ha.)	70000

Average amount of plants per square meter	3.5
Average amount of plants per hectare	35000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of cabbage (kilogram)	2
Average weight of 1 plant of cabbage (gram)	2000

Amount of nutritional benefit a square meter of cabbage will deliver	10472.0974
	418.8838961

Average yield of garden peas per square meter (kg/square meter)	0.4
Average yield of garden peas per hectare (ton/ha.)	4
Average yield of garden peas per hectare (kg/ha.)	4000

Average amount of plants per square meter	13
Average amount of plants per hectare	130000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of garden peas (kilogram)	0.030769231
Average weight of 1 plant of garden peas (gram)	31

Amount of nutritional benefit a square meter of garden peas will deliver	688.3658905
	27.53463562

Average yield of peppers per square meter (kg/square meter)	3
Average yield of peppers per hectare (ton/ha.)	30
Average yield of peppers per hectare (kg/ha.)	30000

Average amount of plants per square meter	3.75
Average amount of plants per hectare	37500
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of peppers (kilogram)	0.8
Average weight of 1 plant of peppers (gram)	800

Amount of nutritional benefit a square meter of peppers will deliver	5247.927006
	209.9170803

Average yield of pumpkin per square meter (kg/square meter)	2.5
Average yield of pumpkin per hectare (ton/ha.)	25
Average yield of pumpkin per hectare (kg/ha.)	25000

Average amount of plants per square meter	0.85
Average amount of plants per hectare	8500
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of pumpkin (kilogram)	2.941176471
Average weight of 1 plant of pumpkin (gram)	2941

Amount of nutritional benefit a square meter of pumpkin will deliver	2814.888685
	112.5955474

Average yield of squash per square meter (kg/square meter)	2.25
Average yield of squash per hectare (ton/ha.)	22.5
Average yield of squash per hectare (kg/ha.)	22500

Average amount of plants per square meter	1.35
Average amount of plants per hectare	13500
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of squash (kilogram)	1.666666667
Average weight of 1 plant of squash (gram)	1667

Amount of nutritional benefit a square meter of squash will deliver	3307.524274
	132.3009709

Average yield of radish per square meter (kg/square meter)	1
Average yield of radish per hectare (ton/ha.)	10
Average yield of radish per hectare (kg/ha.)	10000

Average amount of plants per square meter	100
Average amount of plants per hectare	1000000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of radish (kilogram)	0.01
Average weight of 1 plant of radish (gram)	10

Amount of nutritional benefit a square meter of radish will deliver	1614.031759
	64.56127036

Average yield of corn per square meter (kg/square meter)	2.25
Average yield of corn per hectare (ton/ha.)	22.5
Average yield of corn per hectare (kg/ha.)	22500

Average amount of plants per square meter	7
Average amount of plants per hectare	70000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of corn (kilogram)	0.321428571
Average weight of 1 plant of corn (gram)	321

Amount of nutritional benefit a square meter of corn will deliver	3587.734501
	143.50938

Average yield of turnips per square meter (kg/square meter)	3.25
Average yield of turnips per hectare (ton/ha.)	32.5
Average yield of turnips per hectare (kg/ha.)	32500

Average amount of plants per square meter	30
Average amount of plants per hectare	300000
Amount of square meters in 1 Hectare	10000

Average weight of 1 plant of turnips (kilogram)	0.108333333
Average weight of 1 plant of turnips (gram)	108

Amount of nutritional benefit a square meter of turnips will deliver	3033.873931
	121.3549572

Appendix C:

Linear programs in Lingo

```
model:

!HARVESTED IN March 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg  area_dg  mtm_dg            =
```

price_dg	area_dg	mtm_dg
223.28	19	3
0.00	0	6
0.00	0	2
9.30	11	4
10.98	11	3
0.00	0	3
42.40	6	4

```
;

      price_rody      area_rody    mtm_rody =
```

price_rody	area_rody	mtm_rody
0.00	0	3
54.88	8	3
0.00	0	3
0.00	0	2
220.46	36	1
117.47	17	2

```
;

      price_s         area_s         mtm_s   =
```

price_s	area_s	mtm_s
0.00	0	3
0.00	0	4
180.92	4	3
0.00	0	4
144.65	19	3
49.16	21	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;
```

```
END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:      mtm_s    <= 6);

END
```

```
Global optimal solution found at step:             7
 Objective value:                            352601.1

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        40454.81           0.0000000
                           RODY        17585.95           0.0000000
                              S        294560.4           0.0000000
             PLANT_DG( LETTUCE)        181.1842           0.0000000
              PLANT_DG( ONIONS)       0.0000000           0.0000000
            PLANT_DG( CUCUMBER)       0.0000000           0.0000000
             PLANT_DG( SPINACH)       0.0000000            119.9674
            PLANT_DG( BROCCOLI)       0.0000000            118.2874
         PLANT_DG( GARDEN_PEAS)       0.0000000           0.0000000
             PLANT_DG( CABBAGE)       0.0000000            28.10947
             PRICE_DG( LETTUCE)        223.2800           0.0000000
              PRICE_DG( ONIONS)       0.0000000           0.0000000
            PRICE_DG( CUCUMBER)       0.0000000           0.0000000
             PRICE_DG( SPINACH)        9.300000           0.0000000
            PRICE_DG( BROCCOLI)        10.98000           0.0000000
         PRICE_DG( GARDEN_PEAS)       0.0000000           0.0000000
```

PRICE_DG(CABBAGE)	42.40000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.4000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	28.30000
PLANT_RODY(BEET)	149.7059	0.0000000
PRICE_RODY(TOMATOES)	0.0000000	0.0000000
PRICE_RODY(CARROTS)	54.88000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	220.4600	0.0000000
PRICE_RODY(BEET)	117.4700	0.0000000
AREA_RODY(TOMATOES)	0.0000000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	714.7200
PLANT_S(PUMPKIN)	0.0000000	900.6700
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	180.9200	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	144.6500	0.0000000
PRICE_S(PUMPKIN)	49.16000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	21.00000	0.0000000

MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	352601.1	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	-33.47842
6	0.0000000	-38.32000
7	0.0000000	0.0000000
8	0.0000000	45.23000
9	3.000000	0.0000000
10	0.0000000	0.0000000
11	4.000000	0.0000000
12	2.000000	0.0000000
13	3.000000	0.0000000
14	3.000000	0.0000000
15	2.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

```
model:

!HARVESTED IN April 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;
```

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

price_dg area_dg mtm_dg =

224.20	19	3
0.00	0	6
0.00	0	2
9.34	11	4
11.03	11	3
0.00	0	3
42.57	6	4

;

price_rody area_rody mtm_rody =

117.67	10	3
55.11	8	3
0.00	0	3
0.00	0	2
221.36	36	1
117.96	17	2

;

price_s area_s mtm_s =

0.00	0	3
0.00	0	4
181.66	4	3
0.00	0	4
145.24	19	3
0.00	0	5

;

```
      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:      mtm_s    <= 6);

END



Global optimal solution found at step:            4
 Objective value:                          366333.7

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        40621.50           0.0000000
                           RODY        29947.02           0.0000000
                              S        295765.2           0.0000000
             PLANT_DG( LETTUCE)        181.1842           0.0000000
              PLANT_DG( ONIONS)       0.0000000           0.0000000
            PLANT_DG( CUCUMBER)       0.0000000           0.0000000
             PLANT_DG( SPINACH)       0.0000000            120.4600
            PLANT_DG( BROCCOLI)       0.0000000            118.7700
         PLANT_DG( GARDEN_PEAS)       0.0000000           0.0000000
             PLANT_DG( CABBAGE)       0.0000000            28.23000
             PRICE_DG( LETTUCE)        224.2000           0.0000000
              PRICE_DG( ONIONS)       0.0000000           0.0000000
            PRICE_DG( CUCUMBER)       0.0000000           0.0000000
             PRICE_DG( SPINACH)        9.340000           0.0000000
```

PRICE_DG(BROCCOLI)	11.03000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	42.57000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	254.5000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	39.02600
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	202.2520
PLANT_RODY(BEET)	0.0000000	82.07900
PRICE_RODY(TOMATOES)	117.6700	0.0000000
PRICE_RODY(CARROTS)	55.11000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	221.3600	0.0000000
PRICE_RODY(BEET)	117.9600	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	717.6450
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	181.6600	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	145.2400	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000

AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	366333.7	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	-33.61500
6	0.0000000	-33.64800
7	0.0000000	0.0000000
8	0.0000000	45.41500
9	3.000000	0.0000000
10	0.0000000	0.0000000
11	4.000000	0.0000000
12	2.000000	0.0000000
13	3.000000	0.0000000
14	3.000000	0.0000000
15	2.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

```
model:

!HARVESTED IN May 2010;

!dg   -      DEEP GREEN VEGETABLES;
!rody -      RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -      STARCHY VEGETABLES;
!mtm  -      months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg   =
```

225.12	19	3
0.00	0	6
0.00	0	2
9.38	11	4
0.00	0	3
0.00	0	3
42.75	6	4

;

```
      price_rody   area_rody   mtm_rody =
```

118.15	10	3
55.34	8	3
0.00	0	3
0.00	0	2
0.00	0	1
0.00	0	2

;

```
      price_s   area_s   mtm_s =
```

0.00	0	3
0.00	0	4
182.41	4	3
0.00	0	4
145.84	19	3
0.00	0	5

;

```
      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];        @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];      @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];         @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];             @FOR(vegetables_dg:   mtm_dg    <= 6);
![March_rody];     @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];        @FOR(vegetables_s:      mtm_s     <= 6);

END
```

```
Global optimal solution found at step:             4
 Objective value:                            367843.6
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	40788.19	0.0000000
RODY	30069.18	0.0000000
S	296986.3	0.0000000
PLANT_DG(LETTUCE)	181.1842	0.0000000
PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	0.0000000
PLANT_DG(SPINACH)	0.0000000	120.9526
PLANT_DG(BROCCOLI)	0.0000000	0.0000000
PLANT_DG(GARDEN_PEAS)	0.0000000	0.0000000
PLANT_DG(CABBAGE)	0.0000000	28.34053
PRICE_DG(LETTUCE)	225.1200	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	0.0000000	0.0000000
PRICE_DG(SPINACH)	9.380000	0.0000000

PRICE_DG(BROCCOLI)	0.0000000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	42.75000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	254.5000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	39.18000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	0.0000000
PLANT_RODY(BEET)	0.0000000	0.0000000
PRICE_RODY(TOMATOES)	118.1500	0.0000000
PRICE_RODY(CARROTS)	55.34000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	0.0000000	0.0000000
PRICE_RODY(BEET)	0.0000000	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	0.0000000	0.0000000
AREA_RODY(BEET)	0.0000000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	720.6075
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	182.4100	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	145.8400	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000

AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	367843.6	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	-33.75408
6	0.0000000	-33.78750
7	0.0000000	0.0000000
8	0.0000000	45.60250
9	3.000000	0.0000000
10	0.0000000	0.0000000
11	4.000000	0.0000000
12	2.000000	0.0000000
13	3.000000	0.0000000
14	3.000000	0.0000000
15	2.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

```
model:

!HARVESTED IN June 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg  area_dg  mtm_dg        =
```

0.00	0	3
0.00	0	6
0.00	0	2
9.42	11	4
0.00	0	3
0.00	0	3
0.00	0	4

```
;

      price_rody    area_rody    mtm_rody =
```

0.00	0	3
0.00	0	3
0.00	0	3
0.00	0	2
223.16	36	1
0.00	0	2

```
;

      price_s       area_s        mtm_s  =
```

0.00	0	3
0.00	0	4
0.00	0	3
0.00	0	4
146.43	19	3
0.00	0	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;
```

```
END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:     mtm_s    <= 6);

END
```

```
Global optimal solution found at step:             4
 Objective value:                            68915.01

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        2948.032           0.0000000
                           RODY        15776.17           0.0000000
                              S        50190.81           0.0000000
             PLANT_DG( LETTUCE)       0.0000000           0.0000000
              PLANT_DG( ONIONS)       0.0000000           0.0000000
            PLANT_DG( CUCUMBER)       0.0000000           0.0000000
             PLANT_DG( SPINACH)        312.9545           0.0000000
            PLANT_DG( BROCCOLI)       0.0000000           0.0000000
         PLANT_DG( GARDEN_PEAS)       0.0000000           0.0000000
             PLANT_DG( CABBAGE)       0.0000000           0.0000000
             PRICE_DG( LETTUCE)       0.0000000           0.0000000
              PRICE_DG( ONIONS)       0.0000000           0.0000000
            PRICE_DG( CUCUMBER)       0.0000000           0.0000000
             PRICE_DG( SPINACH)        9.420000           0.0000000
            PRICE_DG( BROCCOLI)       0.0000000           0.0000000
         PRICE_DG( GARDEN_PEAS)       0.0000000           0.0000000
```

PRICE_DG(CABBAGE)	0.0000000	0.0000000
AREA_DG(LETTUCE)	0.0000000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.0000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	70.69444	0.0000000
PLANT_RODY(BEET)	0.0000000	0.0000000
PRICE_RODY(TOMATOES)	0.0000000	0.0000000
PRICE_RODY(CARROTS)	0.0000000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	223.1600	0.0000000
PRICE_RODY(BEET)	0.0000000	0.0000000
AREA_RODY(TOMATOES)	0.0000000	0.0000000
AREA_RODY(CARROTS)	0.0000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	0.0000000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	342.7632	0.0000000
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	146.4300	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000

```
     MTM_S( BUTTERNUT)        3.000000           0.0000000
MTM_S( SWEET_POTATOES)        4.000000           0.0000000
      MTM_S( POTATOES)        3.000000           0.0000000
          MTM_S( CORN)        4.000000           0.0000000
       MTM_S( TURNIPS)        3.000000           0.0000000
       MTM_S( PUMPKIN)        5.000000           0.0000000

                   Row    Slack or Surplus      Dual Price
                     1        68915.01            1.000000
                     2       0.0000000            1.000000
                     3       0.0000000            1.000000
                     4       0.0000000            1.000000
                     5       0.0000000           -6.850478
                     6       0.0000000           -1.507953
                     7       0.0000000           0.0000000
                     8       0.0000000            7.706842
                     9        3.000000           0.0000000
                    10       0.0000000           0.0000000
                    11        4.000000           0.0000000
                    12        2.000000           0.0000000
                    13        3.000000           0.0000000
                    14        3.000000           0.0000000
                    15        2.000000           0.0000000
                    16        3.000000           0.0000000
                    17        3.000000           0.0000000
                    18        3.000000           0.0000000
                    19        4.000000           0.0000000
                    20        5.000000           0.0000000
                    21        4.000000           0.0000000
                    22        3.000000           0.0000000
                    23        2.000000           0.0000000
                    24        3.000000           0.0000000
                    25        2.000000           0.0000000
                    26        3.000000           0.0000000
                    27        1.000000           0.0000000
```

```
model:

!HARVESTED IN July 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg          =
```

226.95	19	3
0	0	6
0.00	0	2
9.46	11	4
0.00	0	3
0.00	0	3
0.00	0	4

```
;

      price_rody      area_rody     mtm_rody  =
```

119.12	10	3
0.00	0	3
0.00	0	3
0.00	0	2
0.00	0	1
119.40	17	2

```
;

      price_s         area_s          mtm_s   =
```

0.00	0	3
0.00	0	4
0.00	0	3
0.00	0	4
0.00	0	3
0.00	0	5

```
;
```

```
      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];        @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];      @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];         @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 4);
![March_rody];     @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];        @FOR(vegetables_s:      mtm_s    <= 6);

END
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	118909.9	0.0000000
RODY	30316.04	0.0000000
S	0.0000000	0.0000000
PLANT_DG(LETTUCE)	523.9474	0.0000000
PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	0.0000000
PLANT_DG(SPINACH)	0.0000000	121.9321
PLANT_DG(BROCCOLI)	0.0000000	0.0000000
PLANT_DG(GARDEN_PEAS)	0.0000000	0.0000000
PLANT_DG(CABBAGE)	0.0000000	0.0000000
PRICE_DG(LETTUCE)	226.9500	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	0.0000000	0.0000000
PRICE_DG(SPINACH)	9.460000	0.0000000
PRICE_DG(BROCCOLI)	0.0000000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	0.0000000	0.0000000

AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	254.5000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.0000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	0.0000000
PLANT_RODY(BEET)	0.0000000	83.10400
PRICE_RODY(TOMATOES)	119.1200	0.0000000
PRICE_RODY(CARROTS)	0.0000000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	0.0000000	0.0000000
PRICE_RODY(BEET)	119.4000	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	0.0000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	0.0000000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	0.0000000
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	0.0000000	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	0.0000000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000

MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	-6514.500	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	6512.500	0.0000000
6	0.0000000	-0.3273684E-01
7	-6512.500	-0.1600000E+08
8	0.0000000	11.94474
9	1.000000	0.0000000
10	-2.000000	0.1600000E+08
11	2.000000	0.0000000
12	0.0000000	0.0000000
13	1.000000	0.0000000
14	1.000000	0.0000000
15	0.0000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

```
model:

!HARVESTED IN August 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:
```

```
        price_dg   area_dg   mtm_dg                =
```

227.87	19	3
0	0	6
0.00	0	2
0.00	0	4
0.00	0	3
0.00	0	3
0.00	0	4

```
;
        price_rody       area_rody     mtm_rody  =
```

0.00	0	3
56.01	8	3
0.00	0	3
0.00	0	2
224.96	36	1
119.88	17	2

```
;

        price_s          area_s           mtm_s   =
```

0.00	0	3
0.00	0	4
0.00	0	3
0.00	0	4
147.62	19	3
0.00	0	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:    (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:      (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];         @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];       @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];          @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;
```

```
      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 5);
![March_rody];     @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];        @FOR(vegetables_s:      mtm_s    <= 6);

END
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	41286.45	0.0000000
RODY	17946.74	0.0000000
S	50598.70	0.0000000
PLANT_DG(LETTUCE)	181.1842	0.0000000
PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	0.0000000
PLANT_DG(SPINACH)	0.0000000	0.0000000
PLANT_DG(BROCCOLI)	0.0000000	0.0000000
PLANT_DG(GARDEN_PEAS)	0.0000000	0.0000000
PLANT_DG(CABBAGE)	0.0000000	0.0000000
PRICE_DG(LETTUCE)	227.8700	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	0.0000000	0.0000000
PRICE_DG(SPINACH)	0.0000000	0.0000000
PRICE_DG(BROCCOLI)	0.0000000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	0.0000000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	0.0000000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.4041176
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	28.90353
PLANT_RODY(BEET)	149.7059	0.0000000
PRICE_RODY(TOMATOES)	0.0000000	0.0000000
PRICE_RODY(CARROTS)	56.01000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000

PRICE_RODY(RADISH)	224.9600	0.0000000
PRICE_RODY(BEET)	119.8800	0.0000000
AREA_RODY(TOMATOES)	0.0000000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	342.7632	0.0000000
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	147.6200	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	-1.000000	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	0.0000000
6	0.0000000	-4.941393
7	0.0000000	-4.223684
8	0.0000000	11.99316
9	2.000000	0.0000000
10	-1.000000	0.3200000E+08
11	3.000000	0.0000000
12	1.000000	0.0000000
13	2.000000	0.0000000
14	2.000000	0.0000000
15	1.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000

```
18          3.000000              0.0000000
19          4.000000              0.0000000
20          5.000000              0.0000000
21          4.000000              0.0000000
22          3.000000              0.0000000
23          2.000000              0.0000000
24          3.000000              0.0000000
25          2.000000              0.0000000
26          3.000000              0.0000000
27          1.000000              0.0000000
```

```
model:

!HARVESTED IN September 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg   =
```

228.79	19	3
0.00	0	6
0.00	0	2
0.00	0	4
0.00	0	3
25.03	86	3
0.00	0	4

```
;
      price_rody   area_rody   mtm_rody  =
```

0.00	0	3
56.24	8	3
0.00	0	3
43.00	18	2
225.86	36	1
120.36	17	2

```
;
```

price_s area_s mtm_s =

0.00	0	3
0.00	0	4
0.00	0	3
0.00	0	4
148.22	19	3
0.00	0	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];        @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];      @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];         @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];             @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];     @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];        @FOR(vegetables_s:      mtm_s    <= 6);

END



Global optimal solution found at step:              4
 Objective value:                            110276.1

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        41453.14           0.0000000
                           RODY        18018.60           0.0000000
                              S        50804.36           0.0000000
              PLANT_DG( LETTUCE)        181.1842           0.0000000
```

PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	0.0000000
PLANT_DG(SPINACH)	0.0000000	0.0000000
PLANT_DG(BROCCOLI)	0.0000000	0.0000000
PLANT_DG(GARDEN_PEAS)	0.0000000	1010.546
PLANT_DG(CABBAGE)	0.0000000	0.0000000
PRICE_DG(LETTUCE)	228.7900	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	0.0000000	0.0000000
PRICE_DG(SPINACH)	0.0000000	0.0000000
PRICE_DG(BROCCOLI)	0.0000000	0.0000000
PRICE_DG(GARDEN_PEAS)	25.03000	0.0000000
PRICE_DG(CABBAGE)	0.0000000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	0.0000000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	86.00000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.4000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	84.44000
PLANT_RODY(RADISH)	0.0000000	29.02000
PLANT_RODY(BEET)	149.7059	0.0000000
PRICE_RODY(TOMATOES)	0.0000000	0.0000000
PRICE_RODY(CARROTS)	56.24000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	43.00000	0.0000000
PRICE_RODY(RADISH)	225.8600	0.0000000
PRICE_RODY(BEET)	120.3600	0.0000000
AREA_RODY(TOMATOES)	0.0000000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	18.00000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	342.7632	0.0000000
PLANT_S(PUMPKIN)	0.0000000	0.0000000

PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	148.2200	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	110276.1	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	0.0000000
6	0.0000000	-4.961579
7	0.0000000	-4.240526
8	0.0000000	12.04158
9	3.000000	0.0000000
10	0.0000000	0.0000000
11	4.000000	0.0000000
12	2.000000	0.0000000
13	3.000000	0.0000000
14	3.000000	0.0000000
15	2.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

27 1.000000 0.0000000

model:

!HARVESTED IN October 2010;

!dg - DEEP GREEN VEGETABLES;
!rody - RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s - STARCHY VEGETABLES;
!mtm - months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

price_dg area_dg mtm_dg =

229.71	19	3
237.03	17	6
26.56	6	2
0.00	0	4
0.00	0	3
25.13	86	3
0.00	0	4

;
price_rody area_rody mtm_rody =

120.57	10	3
56.47	8	3
144.39	11	3
43.17	18	2
226.76	36	1
120.84	17	2

;

price_s area_s mtm_s =

141.99	27	3
27.44	1	4
0.00	0	3
0.00	0	4
148.81	19	3
0.00	0	5

;

total_area = 12500; !Total 50000 sqm area didvided by 4 to create space for monthly cycle;

END DATA

```
max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:      mtm_s    <= 6);

END
```

```
Global optimal solution found at step:            6
 Objective value:                          260108.2
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	47998.58	0.0000000
RODY	33406.60	0.0000000
S	178703.0	0.0000000
PLANT_DG(LETTUCE)	0.0000000	35.20588
PLANT_DG(ONIONS)	202.5000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	57.09765
PLANT_DG(SPINACH)	0.0000000	0.0000000
PLANT_DG(BROCCOLI)	0.0000000	0.0000000
PLANT_DG(GARDEN_PEAS)	0.0000000	1173.963
PLANT_DG(CABBAGE)	0.0000000	0.0000000
PRICE_DG(LETTUCE)	229.7100	0.0000000
PRICE_DG(ONIONS)	237.0300	0.0000000
PRICE_DG(CUCUMBER)	26.56000	0.0000000
PRICE_DG(SPINACH)	0.0000000	0.0000000
PRICE_DG(BROCCOLI)	0.0000000	0.0000000
PRICE_DG(GARDEN_PEAS)	25.13000	0.0000000
PRICE_DG(CABBAGE)	0.0000000	0.0000000
AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	17.00000	0.0000000

AREA_DG(CUCUMBER)	6.000000	0.0000000
AREA_DG(SPINACH)	0.0000000	0.0000000
AREA_DG(BROCCOLI)	0.0000000	0.0000000
AREA_DG(GARDEN_PEAS)	86.00000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	10.69364
PLANT_RODY(CARROTS)	0.0000000	48.54091
PLANT_RODY(PEPPERS)	231.3636	0.0000000
PLANT_RODY(SQUASH)	0.0000000	193.1045
PLANT_RODY(RADISH)	0.0000000	245.7891
PLANT_RODY(BEET)	0.0000000	102.3082
PRICE_RODY(TOMATOES)	120.5700	0.0000000
PRICE_RODY(CARROTS)	56.47000	0.0000000
PRICE_RODY(PEPPERS)	144.3900	0.0000000
PRICE_RODY(SQUASH)	43.17000	0.0000000
PRICE_RODY(RADISH)	226.7600	0.0000000
PRICE_RODY(BEET)	120.8400	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	11.00000	0.0000000
AREA_RODY(SQUASH)	18.00000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	598.8900
PLANT_S(SWEET_POTATOES)	6512.500	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	372.5500
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	141.9900	0.0000000
PRICE_S(SWEET_POTATOES)	27.44000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	148.8100	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	27.00000	0.0000000
AREA_S(SWEET_POTATOES)	1.000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000

```
   MTM_S( CORN)        4.000000           0.0000000
MTM_S( TURNIPS)        3.000000           0.0000000
MTM_S( PUMPKIN)        5.000000           0.0000000

            Row    Slack or Surplus      Dual Price
              1        260108.2            1.000000
              2       0.0000000            1.000000
              3       0.0000000            1.000000
              4       0.0000000            1.000000
              5       0.0000000           -13.49706
              6       0.0000000           -14.31364
              7       0.0000000           0.0000000
              8       0.0000000            27.44000
              9        3.000000           0.0000000
             10       0.0000000           0.0000000
             11        4.000000           0.0000000
             12        2.000000           0.0000000
             13        3.000000           0.0000000
             14        3.000000           0.0000000
             15        2.000000           0.0000000
             16        3.000000           0.0000000
             17        3.000000           0.0000000
             18        3.000000           0.0000000
             19        4.000000           0.0000000
             20        5.000000           0.0000000
             21        4.000000           0.0000000
             22        3.000000           0.0000000
             23        2.000000           0.0000000
             24        3.000000           0.0000000
             25        2.000000           0.0000000
             26        3.000000           0.0000000
             27        1.000000           0.0000000
```

```
model:

!HARVESTED IN November 2010;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg  area_dg  mtm_dg        =
```

230.63	19	3
0.00	0	6
26.67	6	2
9.61	11	4
11.34	11	3
25.23	86	3
0.00	0	4

```
;
      price_rody    area_rody    mtm_rody  =
```

121.05	10	3
59.27	8	3
144.96	11	3
43.34	18	2
227.66	36	1
121.33	17	2

```
;

      price_s       area_s        mtm_s   =
```

142.56	27	3
27.55	1	4
186.87	4	3
50.87	16	4
149.41	19	3
0.00	0	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;
```

```
END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:     mtm_s    <= 6);

END



Global optimal solution found at step:             7
 Objective value:                              379572.7

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        41786.51           0.0000000
                           RODY        33538.47           0.0000000
                              S        304247.7           0.0000000
              PLANT_DG( LETTUCE)       181.1842           0.0000000
               PLANT_DG( ONIONS)      0.0000000           0.0000000
             PLANT_DG( CUCUMBER)      0.0000000            46.16053
              PLANT_DG( SPINACH)      0.0000000            123.9126
             PLANT_DG( BROCCOLI)      0.0000000            122.1826
          PLANT_DG( GARDEN_PEAS)      0.0000000            1018.674
              PLANT_DG( CABBAGE)      0.0000000           0.0000000
              PRICE_DG( LETTUCE)       230.6300           0.0000000
               PRICE_DG( ONIONS)      0.0000000           0.0000000
             PRICE_DG( CUCUMBER)       26.67000           0.0000000
              PRICE_DG( SPINACH)       9.610000           0.0000000
             PRICE_DG( BROCCOLI)       11.34000           0.0000000
          PRICE_DG( GARDEN_PEAS)       25.23000           0.0000000
              PRICE_DG( CABBAGE)      0.0000000           0.0000000
```

AREA_DG(LETTUCE)	19.00000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	6.000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	86.00000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	10.73182
PLANT_RODY(CARROTS)	0.0000000	46.15545
PLANT_RODY(PEPPERS)	231.3636	0.0000000
PLANT_RODY(SQUASH)	0.0000000	193.8673
PLANT_RODY(RADISH)	0.0000000	246.7545
PLANT_RODY(BEET)	0.0000000	102.6991
PRICE_RODY(TOMATOES)	121.0500	0.0000000
PRICE_RODY(CARROTS)	59.27000	0.0000000
PRICE_RODY(PEPPERS)	144.9600	0.0000000
PRICE_RODY(SQUASH)	43.34000	0.0000000
PRICE_RODY(RADISH)	227.6600	0.0000000
PRICE_RODY(BEET)	121.3300	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	11.00000	0.0000000
AREA_RODY(SQUASH)	18.00000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	1118.812
PLANT_S(SWEET_POTATOES)	0.0000000	19.16750
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	696.6100
PLANT_S(TURNIPS)	0.0000000	738.2225
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	142.5600	0.0000000
PRICE_S(SWEET_POTATOES)	27.55000	0.0000000
PRICE_S(POTATOES)	186.8700	0.0000000
PRICE_S(CORN)	50.87000	0.0000000
PRICE_S(TURNIPS)	149.4100	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	27.00000	0.0000000
AREA_S(SWEET_POTATOES)	1.000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	16.00000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000

```
MTM_S( SWEET_POTATOES)        4.000000            0.0000000
      MTM_S( POTATOES)        3.000000            0.0000000
          MTM_S( CORN)        4.000000            0.0000000
       MTM_S( TURNIPS)        3.000000            0.0000000
       MTM_S( PUMPKIN)        5.000000            0.0000000

                   Row    Slack or Surplus      Dual Price
                     1        379572.7            1.000000
                     2       0.0000000            1.000000
                     3       0.0000000            1.000000
                     4       0.0000000            1.000000
                     5       0.0000000           -34.57908
                     6       0.0000000           -33.53932
                     7       0.0000000           0.0000000
                     8       0.0000000            46.71750
                     9        3.000000           0.0000000
                    10       0.0000000           0.0000000
                    11        4.000000           0.0000000
                    12        2.000000           0.0000000
                    13        3.000000           0.0000000
                    14        3.000000           0.0000000
                    15        2.000000           0.0000000
                    16        3.000000           0.0000000
                    17        3.000000           0.0000000
                    18        3.000000           0.0000000
                    19        4.000000           0.0000000
                    20        5.000000           0.0000000
                    21        4.000000           0.0000000
                    22        3.000000           0.0000000
                    23        2.000000           0.0000000
                    24        3.000000           0.0000000
                    25        2.000000           0.0000000
                    26        3.000000           0.0000000
                    27        1.000000           0.0000000
```

model:

!HARVESTED IN December 2010;

!dg - DEEP GREEN VEGETABLES;
!rody - RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s - STARCHY VEGETABLES;
!mtm - months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

price_dg area_dg mtm_dg =

0.00	0	3
0.00	0	6
26.78	6	2
9.65	11	4
11.39	11	3
0.00	0	3
43.98	6	4

;

price_rody area_rody mtm_rody =

121.53	10	3
56.92	8	3
145.54	11	3
43.51	18	2
0.00	0	1
0.00	0	2

;

price_s area_s mtm_s =

143.13	27	3
0.00	0	4
187.62	4	3
51.07	16	4
0.00	0	3
0.00	0	5

;

total_area = 12500; !Total 50000 sqm area didvided by 4 to create space for monthly cycle;

```
END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:      mtm_s    <= 6);

END


Global optimal solution found at step:             4
 Objective value:                            364375.0
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	25233.52	0.0000000
RODY	33672.66	0.0000000
S	305468.8	0.0000000
PLANT_DG(LETTUCE)	0.0000000	0.0000000
PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	0.0000000	17.20000
PLANT_DG(SPINACH)	0.0000000	70.98000
PLANT_DG(BROCCOLI)	0.0000000	69.24000
PLANT_DG(GARDEN_PEAS)	0.0000000	0.0000000
PLANT_DG(CABBAGE)	573.7500	0.0000000
PRICE_DG(LETTUCE)	0.0000000	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	26.78000	0.0000000
PRICE_DG(SPINACH)	9.650000	0.0000000
PRICE_DG(BROCCOLI)	11.39000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	43.98000	0.0000000
AREA_DG(LETTUCE)	0.0000000	0.0000000

AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	6.000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	10.77909
PLANT_RODY(CARROTS)	0.0000000	48.92727
PLANT_RODY(PEPPERS)	231.3636	0.0000000
PLANT_RODY(SQUASH)	0.0000000	194.6464
PLANT_RODY(RADISH)	0.0000000	0.0000000
PLANT_RODY(BEET)	0.0000000	0.0000000
PRICE_RODY(TOMATOES)	121.5300	0.0000000
PRICE_RODY(CARROTS)	56.92000	0.0000000
PRICE_RODY(PEPPERS)	145.5400	0.0000000
PRICE_RODY(SQUASH)	43.51000	0.0000000
PRICE_RODY(RADISH)	0.0000000	0.0000000
PRICE_RODY(BEET)	0.0000000	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	11.00000	0.0000000
AREA_RODY(SQUASH)	18.00000	0.0000000
AREA_RODY(RADISH)	0.0000000	0.0000000
AREA_RODY(BEET)	0.0000000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	1123.305
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	699.4100
PLANT_S(TURNIPS)	0.0000000	0.0000000
PLANT_S(PUMPKIN)	0.0000000	0.0000000
PRICE_S(BUTTERNUT)	143.1300	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	187.6200	0.0000000
PRICE_S(CORN)	51.07000	0.0000000
PRICE_S(TURNIPS)	0.0000000	0.0000000
PRICE_S(PUMPKIN)	0.0000000	0.0000000
AREA_S(BUTTERNUT)	27.00000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	16.00000	0.0000000
AREA_S(TURNIPS)	0.0000000	0.0000000
AREA_S(PUMPKIN)	0.0000000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000

```
MTM_S( POTATOES)        3.000000             0.0000000
    MTM_S( CORN)        4.000000             0.0000000
 MTM_S( TURNIPS)        3.000000             0.0000000
 MTM_S( PUMPKIN)        5.000000             0.0000000

             Row    Slack or Surplus      Dual Price
               1        364375.0             1.000000
               2       0.0000000             1.000000
               3       0.0000000             1.000000
               4       0.0000000             1.000000
               5       0.0000000            -39.57500
               6       0.0000000            -33.67409
               7       0.0000000             0.0000000
               8       0.0000000             46.90500
               9        3.000000             0.0000000
              10       0.0000000             0.0000000
              11        4.000000             0.0000000
              12        2.000000             0.0000000
              13        3.000000             0.0000000
              14        3.000000             0.0000000
              15        2.000000             0.0000000
              16        3.000000             0.0000000
              17        3.000000             0.0000000
              18        3.000000             0.0000000
              19        4.000000             0.0000000
              20        5.000000             0.0000000
              21        4.000000             0.0000000
              22        3.000000             0.0000000
              23        2.000000             0.0000000
              24        3.000000             0.0000000
              25        2.000000             0.0000000
              26        3.000000             0.0000000
              27        1.000000             0.0000000
```

```
model:

!HARVESTED IN January 2011;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg          =
```

0.00	0	3
0.00	0	6
26.88	6	2
9.69	11	4
11.43	11	3
0.00	0	3
0.00	0	4

```
;
      price_rody      area_rody     mtm_rody  =
```

122.01	10	3
0.00	0	3
0.00	0	3
0.00	0	2
229.46	36	1
0.00	0	2

```
;

      price_s         area_s          mtm_s   =
```

143.70	27	3
0.00	0	4
-	0	3
51.28	16	4
0.00	0	3
51.20	21	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA
```

```
max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:      (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];        @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];      @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];         @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];             @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];     @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];        @FOR(vegetables_s:      mtm_s    <= 6);

END
```

```
Global optimal solution found at step:              5
 Objective value:                             81134.92
```

Variable	Value	Reduced Cost
TOTAL_AREA	12500.00	0.0000000
DG	15422.40	0.0000000
RODY	31051.54	0.0000000
S	34660.97	0.0000000
PLANT_DG(LETTUCE)	0.0000000	0.0000000
PLANT_DG(ONIONS)	0.0000000	0.0000000
PLANT_DG(CUCUMBER)	573.7500	0.0000000
PLANT_DG(SPINACH)	0.0000000	39.59000
PLANT_DG(BROCCOLI)	0.0000000	37.85000
PLANT_DG(GARDEN_PEAS)	0.0000000	0.0000000
PLANT_DG(CABBAGE)	0.0000000	0.0000000
PRICE_DG(LETTUCE)	0.0000000	0.0000000
PRICE_DG(ONIONS)	0.0000000	0.0000000
PRICE_DG(CUCUMBER)	26.88000	0.0000000
PRICE_DG(SPINACH)	9.690000	0.0000000
PRICE_DG(BROCCOLI)	11.43000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	0.0000000	0.0000000
AREA_DG(LETTUCE)	0.0000000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000

AREA_DG(CUCUMBER)	6.000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	0.0000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	254.5000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.0000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	209.7760
PLANT_RODY(BEET)	0.0000000	0.0000000
PRICE_RODY(TOMATOES)	122.0100	0.0000000
PRICE_RODY(CARROTS)	0.0000000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	229.4600	0.0000000
PRICE_RODY(BEET)	0.0000000	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	0.0000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	0.0000000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	241.2037	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	0.0000000	33.87556
PLANT_S(TURNIPS)	0.0000000	0.0000000
PLANT_S(PUMPKIN)	0.0000000	60.56667
PRICE_S(BUTTERNUT)	143.7000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	51.28000	0.0000000
PRICE_S(TURNIPS)	0.0000000	0.0000000
PRICE_S(PUMPKIN)	51.20000	0.0000000
AREA_S(BUTTERNUT)	27.00000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	16.00000	0.0000000
AREA_S(TURNIPS)	0.0000000	0.0000000
AREA_S(PUMPKIN)	21.00000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000

```
   MTM_S( CORN)        4.000000            0.0000000
MTM_S( TURNIPS)        3.000000            0.0000000
MTM_S( PUMPKIN)        5.000000            0.0000000

            Row    Slack or Surplus      Dual Price
              1        81134.92            1.000000
              2       0.0000000            1.000000
              3       0.0000000            1.000000
              4       0.0000000            1.000000
              5       0.0000000           -7.721000
              6       0.0000000           0.0000000
              7       0.0000000           -6.878778
              8       0.0000000            12.20100
              9        3.000000           0.0000000
             10       0.0000000           0.0000000
             11        4.000000           0.0000000
             12        2.000000           0.0000000
             13        3.000000           0.0000000
             14        3.000000           0.0000000
             15        2.000000           0.0000000
             16        3.000000           0.0000000
             17        3.000000           0.0000000
             18        3.000000           0.0000000
             19        4.000000           0.0000000
             20        5.000000           0.0000000
             21        4.000000           0.0000000
             22        3.000000           0.0000000
             23        2.000000           0.0000000
             24        3.000000           0.0000000
             25        2.000000           0.0000000
             26        3.000000           0.0000000
             27        1.000000           0.0000000
```

```
model:


model:

!HARVESTED IN February 2011;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/:
plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody,
price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s,
price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg              =
```

0.00	0	3
0.00	0	6
0.00	0	2
9.72	11	4
11.48	11	3
0.00	0	3
44.33	6	4

```
;
      price_rody      area_rody     mtm_rody  =
```

122.49	10	3
0.00	0	3
0.00	0	3
0.00	0	2
230.36	36	1
122.77	17	2

```
;

      price_s        area_s          mtm_s   =
```

0.00	0	3
0.00	0	4
0.00	0	3
51.48	16	4
0.00	0	3
51.41	21	5

```
;
```

```
      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space
for monthly cycle;

END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];         @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];       @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];          @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];              @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];      @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];         @FOR(vegetables_s:      mtm_s    <= 6);

END
```

```
Global optimal solution found at step:              3
 Objective value:                            77562.01

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        25434.34           0.0000000
                           RODY        31173.70           0.0000000
                              S        20953.97           0.0000000
              PLANT_DG( LETTUCE)      0.0000000           0.0000000
               PLANT_DG( ONIONS)      0.0000000           0.0000000
             PLANT_DG( CUCUMBER)      0.0000000           0.0000000
              PLANT_DG( SPINACH)      0.0000000            71.55167
             PLANT_DG( BROCCOLI)      0.0000000            69.79167
         PLANT_DG( GARDEN_PEAS)      0.0000000           0.0000000
              PLANT_DG( CABBAGE)       573.7500           0.0000000
              PRICE_DG( LETTUCE)      0.0000000           0.0000000
               PRICE_DG( ONIONS)      0.0000000           0.0000000
             PRICE_DG( CUCUMBER)      0.0000000           0.0000000
              PRICE_DG( SPINACH)       9.720000           0.0000000
```

PRICE_DG(BROCCOLI)	11.48000	0.0000000
PRICE_DG(GARDEN_PEAS)	0.0000000	0.0000000
PRICE_DG(CABBAGE)	44.33000	0.0000000
AREA_DG(LETTUCE)	0.0000000	0.0000000
AREA_DG(ONIONS)	0.0000000	0.0000000
AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	254.5000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.0000000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	210.6040
PLANT_RODY(BEET)	0.0000000	85.46300
PRICE_RODY(TOMATOES)	122.4900	0.0000000
PRICE_RODY(CARROTS)	0.0000000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	230.3600	0.0000000
PRICE_RODY(BEET)	122.7700	0.0000000
AREA_RODY(TOMATOES)	10.00000	0.0000000
AREA_RODY(CARROTS)	0.0000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	0.0000000	0.0000000
PLANT_S(CORN)	407.0312	0.0000000
PLANT_S(TURNIPS)	0.0000000	0.0000000
PLANT_S(PUMPKIN)	0.0000000	16.15750
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	0.0000000	0.0000000
PRICE_S(CORN)	51.48000	0.0000000
PRICE_S(TURNIPS)	0.0000000	0.0000000
PRICE_S(PUMPKIN)	51.41000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	0.0000000	0.0000000
AREA_S(CORN)	16.00000	0.0000000

AREA_S(TURNIPS)	0.0000000	0.0000000
AREA_S(PUMPKIN)	21.00000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000
MTM_S(CORN)	4.000000	0.0000000
MTM_S(TURNIPS)	3.000000	0.0000000
MTM_S(PUMPKIN)	5.000000	0.0000000

Row	Slack or Surplus	Dual Price
1	77562.01	1.000000
2	0.0000000	1.000000
3	0.0000000	1.000000
4	0.0000000	1.000000
5	0.0000000	-4.860667
6	0.0000000	0.0000000
7	0.0000000	-9.031500
8	0.0000000	12.24900
9	3.000000	0.0000000
10	0.0000000	0.0000000
11	4.000000	0.0000000
12	2.000000	0.0000000
13	3.000000	0.0000000
14	3.000000	0.0000000
15	2.000000	0.0000000
16	3.000000	0.0000000
17	3.000000	0.0000000
18	3.000000	0.0000000
19	4.000000	0.0000000
20	5.000000	0.0000000
21	4.000000	0.0000000
22	3.000000	0.0000000
23	2.000000	0.0000000
24	3.000000	0.0000000
25	2.000000	0.0000000
26	3.000000	0.0000000
27	1.000000	0.0000000

```
model:

!HARVESTED IN March 2011;

!dg   -     DEEP GREEN VEGETABLES;
!rody -     RED, ORANGE AND DEEP YELLOW VEGETABLES;
!s    -     STARCHY VEGETABLES;
!mtm  -     months to maturity;

SETS: vegetables_dg /Lettuce,Onions, Cucumber, Spinach, Broccoli, Garden_peas, Cabbage/: plant_dg, price_dg, area_dg, mtm_dg;
      vegetables_rody / Tomatoes, Carrots, Peppers, Squash, Radish, Beet/: plant_rody, price_rody,area_rody, mtm_rody;
      vegetables_s / Butternut, Sweet_potatoes, Potatoes, Corn, Turnips, Pumpkin/: plant_s, price_s,area_s, mtm_s;

END SETS

DATA:

      price_dg   area_dg   mtm_dg        =
```

234.30	19	3
0.00	0	6
0.00	0	2
9.76	11	4
11.52	11	3
0.00	0	3
44.50	6	4

```
;
      price_rody      area_rody     mtm_rody  =
```

0.00	0	3
57.59	8	3
0.00	0	3
0.00	0	2
231.26	36	1
123.25	17	2

```
;

      price_s         area_s         mtm_s   =
```

0.00	0	3
0.00	0	4
189.85	4	3
0.00	0	4
151.79	19	3
51.61	21	5

```
;

      total_area = 12500; !Total 50000 sqm area didvided by 4 to create space for monthly cycle;
```

```
END DATA


max = dg + rody + s;

dg = (@SUM( vegetables_dg:   (price_dg*plant_dg)));
rody = (@SUM(vegetables_rody: (price_rody*plant_rody)));
S = (@SUM(vegetables_s:     (price_s*plant_s)));

![Subject to];

!Balanced meal;
![Area_dg];       @SUM (vegetables_dg: (area_dg*plant_dg)) >=
0.2754*total_area; !Balanced meal area for Dark Green vegetables;
![Area_rody];     @SUM (vegetables_rody: (area_rody*plant_rody)) >=
0.2036*total_area; !Balanced meal area for Dark Green vegetables;
![Area_s];        @SUM (vegetables_s: (area_s*plant_s)) >= 0.5210*total_area;
!Balanced meal area for Dark Green vegetables;


!Area constraint;

      ((@SUM (vegetables_dg: (area_dg*plant_dg)))
      +(@SUM(vegetables_rody: (area_rody*plant_rody)))
       +(@SUM(vegetables_s:    (area_s*plant_s)))) <= total_area;

![March_dg];            @FOR(vegetables_dg:   mtm_dg   <= 6);
![March_rody];    @FOR(vegetables_rody: mtm_rody <= 6);
![March_s];       @FOR(vegetables_s:      mtm_s    <= 6);

END
```

```
Global optimal solution found at step:            7
 Objective value:                           370002.2

                       Variable           Value        Reduced Cost
                     TOTAL_AREA        12500.00           0.0000000
                             DG        42451.46           0.0000000
                           RODY        18451.25           0.0000000
                              S        309099.5           0.0000000
              PLANT_DG( LETTUCE)       181.1842           0.0000000
               PLANT_DG( ONIONS)      0.0000000           0.0000000
             PLANT_DG( CUCUMBER)      0.0000000           0.0000000
              PLANT_DG( SPINACH)      0.0000000            125.8874
             PLANT_DG( BROCCOLI)      0.0000000            124.1274
          PLANT_DG( GARDEN_PEAS)      0.0000000           0.0000000
              PLANT_DG( CABBAGE)      0.0000000            29.48947
              PRICE_DG( LETTUCE)       234.3000           0.0000000
               PRICE_DG( ONIONS)      0.0000000           0.0000000
             PRICE_DG( CUCUMBER)      0.0000000           0.0000000
              PRICE_DG( SPINACH)       9.760000           0.0000000
             PRICE_DG( BROCCOLI)       11.52000           0.0000000
          PRICE_DG( GARDEN_PEAS)      0.0000000           0.0000000
              PRICE_DG( CABBAGE)       44.50000           0.0000000
               AREA_DG( LETTUCE)       19.00000           0.0000000
                AREA_DG( ONIONS)      0.0000000           0.0000000
```

AREA_DG(CUCUMBER)	0.0000000	0.0000000
AREA_DG(SPINACH)	11.00000	0.0000000
AREA_DG(BROCCOLI)	11.00000	0.0000000
AREA_DG(GARDEN_PEAS)	0.0000000	0.0000000
AREA_DG(CABBAGE)	6.000000	0.0000000
MTM_DG(LETTUCE)	3.000000	0.0000000
MTM_DG(ONIONS)	6.000000	0.0000000
MTM_DG(CUCUMBER)	2.000000	0.0000000
MTM_DG(SPINACH)	4.000000	0.0000000
MTM_DG(BROCCOLI)	3.000000	0.0000000
MTM_DG(GARDEN_PEAS)	3.000000	0.0000000
MTM_DG(CABBAGE)	4.000000	0.0000000
PLANT_RODY(TOMATOES)	0.0000000	0.0000000
PLANT_RODY(CARROTS)	0.0000000	0.4100000
PLANT_RODY(PEPPERS)	0.0000000	0.0000000
PLANT_RODY(SQUASH)	0.0000000	0.0000000
PLANT_RODY(RADISH)	0.0000000	29.74000
PLANT_RODY(BEET)	149.7059	0.0000000
PRICE_RODY(TOMATOES)	0.0000000	0.0000000
PRICE_RODY(CARROTS)	57.59000	0.0000000
PRICE_RODY(PEPPERS)	0.0000000	0.0000000
PRICE_RODY(SQUASH)	0.0000000	0.0000000
PRICE_RODY(RADISH)	231.2600	0.0000000
PRICE_RODY(BEET)	123.2500	0.0000000
AREA_RODY(TOMATOES)	0.0000000	0.0000000
AREA_RODY(CARROTS)	8.000000	0.0000000
AREA_RODY(PEPPERS)	0.0000000	0.0000000
AREA_RODY(SQUASH)	0.0000000	0.0000000
AREA_RODY(RADISH)	36.00000	0.0000000
AREA_RODY(BEET)	17.00000	0.0000000
MTM_RODY(TOMATOES)	3.000000	0.0000000
MTM_RODY(CARROTS)	3.000000	0.0000000
MTM_RODY(PEPPERS)	3.000000	0.0000000
MTM_RODY(SQUASH)	2.000000	0.0000000
MTM_RODY(RADISH)	1.000000	0.0000000
MTM_RODY(BEET)	2.000000	0.0000000
PLANT_S(BUTTERNUT)	0.0000000	0.0000000
PLANT_S(SWEET_POTATOES)	0.0000000	0.0000000
PLANT_S(POTATOES)	1628.125	0.0000000
PLANT_S(CORN)	0.0000000	0.0000000
PLANT_S(TURNIPS)	0.0000000	749.9975
PLANT_S(PUMPKIN)	0.0000000	945.1025
PRICE_S(BUTTERNUT)	0.0000000	0.0000000
PRICE_S(SWEET_POTATOES)	0.0000000	0.0000000
PRICE_S(POTATOES)	189.8500	0.0000000
PRICE_S(CORN)	0.0000000	0.0000000
PRICE_S(TURNIPS)	151.7900	0.0000000
PRICE_S(PUMPKIN)	51.61000	0.0000000
AREA_S(BUTTERNUT)	0.0000000	0.0000000
AREA_S(SWEET_POTATOES)	0.0000000	0.0000000
AREA_S(POTATOES)	4.000000	0.0000000
AREA_S(CORN)	0.0000000	0.0000000
AREA_S(TURNIPS)	19.00000	0.0000000
AREA_S(PUMPKIN)	21.00000	0.0000000
MTM_S(BUTTERNUT)	3.000000	0.0000000
MTM_S(SWEET_POTATOES)	4.000000	0.0000000
MTM_S(POTATOES)	3.000000	0.0000000

```
    MTM_S( CORN)        4.000000         0.0000000
 MTM_S( TURNIPS)        3.000000         0.0000000
 MTM_S( PUMPKIN)        5.000000         0.0000000

             Row    Slack or Surplus      Dual Price
               1        370002.2            1.000000
               2       0.0000000            1.000000
               3       0.0000000            1.000000
               4       0.0000000            1.000000
               5       0.0000000           -35.13092
               6       0.0000000           -40.21250
               7       0.0000000           0.0000000
               8       0.0000000            47.46250
               9        3.000000           0.0000000
              10       0.0000000           0.0000000
              11        4.000000           0.0000000
              12        2.000000           0.0000000
              13        3.000000           0.0000000
              14        3.000000           0.0000000
              15        2.000000           0.0000000
              16        3.000000           0.0000000
              17        3.000000           0.0000000
              18        3.000000           0.0000000
              19        4.000000           0.0000000
              20        5.000000           0.0000000
              21        4.000000           0.0000000
              22        3.000000           0.0000000
              23        2.000000           0.0000000
              24        3.000000           0.0000000
              25        2.000000           0.0000000
              26        3.000000           0.0000000
              27        1.000000           0.0000000
```