ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 6, Issue, 1, pp.2424-2427, January, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

A MATHEMATICAL APPROACH TO OPTIMIZE SEED SELECTION PROCESS IN PERMACULTURE

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ARTICLE INFO

Article History:

Received 14th, December, 2014
Received in revised form 23th, December, 2014
Accepted 13th, January, 2015
Published online 28th, January, 2015

Key words:

architectural approach, intelligent defense, organizational modeling

ABSTRACT

As a stepping stone towards achieving a concept of resource-independence from artificial and synthesized agricultural materials, an organic gardening approach is followed using seed selection criterion. In this paper, the seed selection will be shown for its importance in maximizing the revenue in Kuwait where the environment is a challenge to grow plants organically. The potential of such idea is its input in achieving what is known as permaculture.

INTRODUCTION

The concept of permaculture seeks the survival of food recourses, hence the name permaculture derived from permanent agriculture. The goal is to device an environment where a sustainable food can be devised through organic or less synthesized conventional methods while still sustaining the demand of numerous consumers worldwide [1].

The organic farming of plants is heavily dependent on the climate at which the plants can grow. The case study is taken in Wafra fields, which are the most fertile lands located at the southern regions of Kuwait. Organic farming is generally a costly field, where the products could be damaged through series of operations unexpectedly. Organic growing countries have their share of organic food to be costly and scarce due to its water costs and demanding labor requirements.

The seed selection comes in handy when the costs of such procedure is significantly reduced, which is the case when taken each aspect with the work laws of Kuwait. The challenge comes when dealing with the weather and the water demand increase ensued. The seed selection would serve to benefit the outcome of such goal of achieving a good profit in a harsh weather.

Vision of Permaculture

The permaculture movement is to aspire for coexisting with the finite recourse on earth and live in resonance with them with minimal interference from technology. At the end of the day, if an ecological human habitat can be achieved through natural means, then the existence of human race can be justified for longer periods of time. Codes and ethics are introduced amongst the enthusiastic practitioners of permaculture to account for broad or narrow fields either related to size of application or location of application taken [2]. The permaculture model is to create a self-maintained system that exists in order to develop a viable food recourses modeled from natural ecosystems. One of the many design principle of the permaculture system is to obtain a yield. The system requires work from its residents that must be rewarded enough through a gross yield in food recourses. The main aim of such concept is to work with nature to get a feasible outcome that can be used to coexist with nature as equals.

Different techniques were introduced to achieve such a goal, such as Agroforestry. This approach utilizes the benefits of combining trees and shrubs with crops and livestock. The results are diversity in inland use technology that exploits the different interactions of forests to be applied to the crop and life stock in it designated permaculture zone. However, ecological succession causes the decline of forest productivity, which faced many criticisms when choosing Agroforestry as a permaculture based approach. It is tempting to use forestry gardens due to its capabilities to achieve perpetual stability through time, which is the result of ecological succession [3]. Although, the yield would decline significantly after that stage of ecosystem is reached full maturity after. Hence, the seed selection is a powerful tool to be included in the design for permaculture where it takes the factors of weather, water and interactions with other plants to maximize the yield revenue as a first step to achieve in the desired permaculture ecosystem.

Plants Synergy and Compatibility

One of the basics of permaculture is to find a type of efficiency in ecosystem that takes advantage of relationships exist between different species of life, plants or life stock. An undeniably fundamental principle of permaculture presented by the co-originator of the idea, David Holmgren [4], is to integrate rather than segregate. This informs us that each part of the ecosystem must be placed in such a pattern that can utilize different species' interactions and relationships in order to find some kind of support around the ecosystem. This must be taken into consideration when growing plants and plants preparation after harvest. So, the seed selection procedure incorporates such principle.

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Plants need a lot of materials provided in the farming soil that facilitates its germination process. One such substance is nitrogen. It is a known fact that vegetables need nitrogen to sprout and provide better yield, to the point where fertilizers come in handy. However, using the mentioned principle, the fertilizer may be replaced with a more environmentally welcomed substitute that requires no synthesized fabricated products.

Adding nitrogen to legumes plants would delay their growth and return less than good quality of beans or whatever is harvested. This is due to the fact that the legume plants release nitrogen into the soul. Such release of substance can be utilized for replacement of fertilizers. Leading to relieve of soil treatments, such option is immensely attractive.

Farmers usually separate their land if they decide to grow both of these products. The portion of the land that yielded legumes is not used to grow legumes after harvest. The soil would contain high percentages of nitrogen that simply hinders the growing process of legumes as previously mentioned. As such, this portion of land is instead prepared for vegetables, which require nitrogen for better growth rates. After vegetable harvest, the portion is prepared for the next batch of legumes and the cycle continues as it should. This method is a classic example of synergy and compatibility between species that can be employed for our benefit. Such option is extremely favored by organic farm enthusiasts, who have been struggling with plant treatment by the use of bacteria and other complex methods. This can be under another principle of perm culture proposed by David Holmgren, which is to use renewable resources to reduce non-renewable energy consumption and make use of.

As for seed selection goes, portions of previously grown vegetables or legumes portions of land must be identified before commencing into the procedure while upholding the purpose of this research, which is to provide a maximized revenue of land proposed by a proper and environmentally friendly organic farming.

Developed Countries Perspective of Seed Selection Cost Analysis

Organic farming suffers from abundance of criticism due to its vulnerability to weather and other factors that can be as trivial as water availability. In the developed countries, the organic farming took a good lead, which results in a regular supply of organic products in food markets and other institutions. One other criticism is the market price of the products [5].

First world countries come in as one of the most expensive countries for living expense such as water. A greater capital is hence provided to cover such a cost to force in the start of organic farming harvest. labor and seed requirement comes in after. Organic farming needs more care and attention than regular farming [6], which raise the labor fees significantly under strict rules of designated authorities of first world countries' labor laws. The seed is no exception.

Design Approach of Seed selection as a milestone of Perm culture

The power in seed selection lies in the ability to project the profit made on each seed's germination period alongside its cost related to hand work and agricultural field demands [7]. The seed selection must be done in such a way that it can relate to some of the permaculture's characteristics for an organic harvest. One of the principles that are encountered when dealing with permaculture would be the synergy and compatibility of plants. The factors considered in this study are illustrated in the table below:

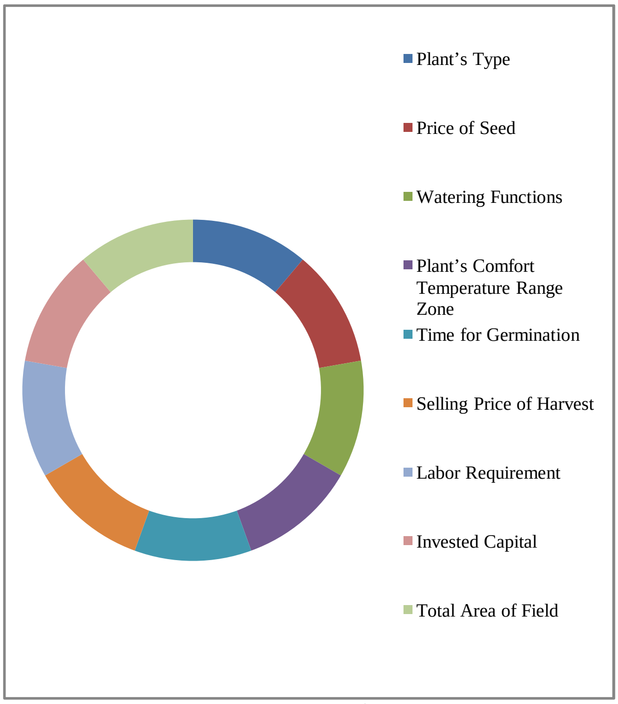

Figure 1 Seed Selection Factors of Optimization Analysis.

Optimization Selection

The Problem at hand needs to be handled with proper optimization algorithm that can supply the selection of the seed while distributing the area of the farmland to satisfy the objective function of the analysis at hand. One obvious consideration is the setting the problem at hand as a facility location problem (K-center, K-median) [8], especially since such analysis of permaculture is significantly dependent on plants compatibility conditions as mentioned before.

While the facility location algorithm looks promising, however, the reported limitation of the analysis method is due to its capabilities of considerable alteration of the final solution. Such alterations are generated from what is called outliers, which few of them have the capability of changing the final outcome substantially. For example, the K-center method (a min-max problem) may alter the center of the optimum solution due to the existence of a distant outlier to be placed around its surrounding area [8].

The references for the data in Table 1 below are from [9],[10],[11],[12] and [13]

The Cost of water, labor and seed purchase prices is included in the total budget of the growing period of each plant.
The objective function is:

$$Maxmize\ Profit(x) = 50 \sum_{i=1}^{15} cixi \qquad (1)$$

Where c_i is total revenue for seed i. The land is discretized into areas of 50 square meters and the coefficient of the capital constrain are of the budget of each plants during its lifetime on a 50 square meter of land:

$$\sum_{i=1}^{15} p_i x_i \leq P \qquad (2)$$

Where p_i is the cost for seed i and P is the total available amount to invest. All these steps must be verified for the entire period of harvest with the atmospheric temperature compatibility. Afterwards, the total area must not be exceeded obviously:

$$50\sum_{i=1}^{15} x_i \leq L \qquad (3)$$

Where L is the total area for plantation. In (3) all the coefficients values are 50 meter. This is because the area is discretized into smaller areas of 50 meter (as a minimum) and the objective is to find the values that would fill up the area. The same process is conducted for areas where legumes or vegetable were harvested recently. Instead of taking all the coefficients, the coefficients of legume must not exceed the remaining area excluding the legume area and the same goes for vegetables.

x_i= 0 or 1 i=1,2,3…15 (4)

Case Study of Seed Selection

As a simplified example, an area of 2000 m^2 is taken for a seed selection problem with a capital of \$50,000. It is assumed that the land was not previously grown with either vegetables or legumes. As such, the area is discretized into 40 areas of 50 m^2 and the results should be an integer that is to be multiplied by 50 to evaluate each selected seed's coverage area of the total land. In this example, the area is taken as an entire field of white radish, giving an integer result of 40 describing the number of areas of 50 m^2 to be covered by white radish with profit of around \$9500. This can be described as the maximum profit that can be obtained with a cost of 2000 m^2 of white radish (coat is about \$1500).

Such values are promising since the costs of growing these plants are relatively cheap if taken in areas where water and labor fees are low. Suppose for an example, that quarter of the land (500 m^2) was previously grown with vegetables. So, if the simplex method is run again, than the area of vegetables cannot exceed 1500 m^2 on account for the previously vegetable portion of land. This would generate a result of about 1500 m^2 of land of radish or white radish and the rest is distributed

Table 1 Data Collected for Selected Data Set of Seeds.

Seed	Seed price \$ per lb.	Required water gallons per acre-day	Minimum germination temperature ^{O}F	Maximum germination temperature ^{O}F	Harvest time in days	Selling price (profit) \$ per lb.	Net Price\$
tomatoes	72	271540	65	75	35	6.40	63.15
onion	62	3879	55	65	70	1.69	8.27
garlic	1	3103	55.4	75.2	180	10.00	17.83
Parsnip	13	3879	50	65	30	80.00	237.22
radish	13	3879	50	65	30	80.00	237.22
carrot	28	40731	50	75	70	5.47	29.59
cantaloupe	28	7758	60	75	21	1.29	3.12
watermelon	28	3879	65	80	21	0.79	2.01
cucumber	28	7758	60	75	21	2.50	5.19
zucchini	28	5818	70	95	120	2.50	13.83
pepper	62	5818	60	75	42	5.00	8.53
lettuce	18	5818	50	80	35	3.50	11.16
eggplant	38	3879	65	80	42	3.50	28.89
beans	11	13577	71.6	104	20	3.25	3.69
purslane	2.3	3103	58.1	111.02	150	7.00	6.92

The following summarize the steps taken to produce the seed distribution of any land chosen for such purpose:

1. The capital willing to be invested is specified.
2. The Total area of the land is also taken before enquiring whether the land was previously grown with either vegetables or legumes.
3. If the land was previously used to grow either vegetables or legumes, then the area at which either of them was grown in must be specified.
4. The total area is dissected into small areas of 50 m^2 along with knowing how much of the land can be distributed.
5. For each seed's time to germinate, the maximum and minimum germination temperatures are checked with every maximum and minimum temperature of every day in the year to specify a preferable starting date for growing.
6. The water, seed price and labor are taken as the cost constraint of the process.
7. The second constraint is the total area of the land, along with the area of previously grown vegetables or legumes.
8. Using the simplex method to produce the selected seeds and area coverage of each seed.

between cantaloupe (100 m^2), watermelon (100 m^2), cucumber (200 m^2) and eggplant (50 m^2), totaling in a profit about \$7200. The last two plants are considered to be a fruit in germination perspectives. A sample land distribution for a square property can be illustrated by the image below.

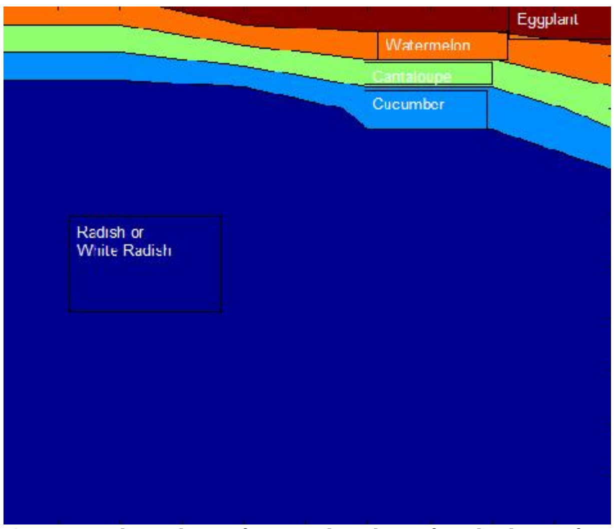

Figure 2 Land Distribution for Second Analysis of Seed Selection for a Square Shaped Land Property.

CONCLUSION

The purpose of this study is to demonstrate a practical use of some of the known principles of permaculture to be used in organic farming of some plants in harsh weather conditions. Such analysis is demonstrated through an optimization problem that produces the land distributions of farmlands that are necessary to optimize the revenue without resorting to conventional means.

The seed selection process proves to be a wide scale problem when considering the large scale of seed types existing in the world along with the some essential principle of permaculture such as compatibility as mentioned before. The need of seed selection is improved through an optimization analysis that should regard such principles into mind while keeping in mind that the means used are purely organic.

The weather conditions of some areas, such as Wafra fields in Kuwait, prove to be harsh for most plants. However, such areas would be useful when minimizing the operating cost of such tedious process. Hence, for a smaller amount of capital, it is proven that a profitable organic farming could be achieved when dealing with such circumstances. The problem could be expanded further to include wild stock in the permaculture field and introduce some mechanical, environmentally friendly designs that helps achieve more independence from conventional means of supplying sustenance.

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