Determining a Quantitative Decision Metric of Best Use of Land at Syracuse

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Abstract:

Mathematical models have been extensively used in optimization. An important application is maximizing the usage of land resources. Such models can help policymakers with the long-term goals of sustainable development. We have a piece of 3 km of land near Syracuse, New York, between the boundaries of Red Creek Road, Upton Road, Maiden Road, and Maroney Road. The decision-makers have considered the options of the outdoor sports complex, x cross-country skiing facility (3-month season), a crop farm, a grazing farm/ranch, a regenerative farm, a solar array, an agrivoltaic farm, and an agritourist center. We have built a linear model that presents an optimal solution based on the climate and geographical parameters of the land. Our model also incorporates environmental factors like carbon emission and aims at sustainable land usage alongside maximizing the economic benefits. The paper has been sent along with a letter of recommendation to encourage the policymakers on this approach.

Keywords — **decision metric, net present value, linear programming, optimization**

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I. INTRODUCTION

Optimal use of land must consider factors such as environmental impact, short term, and long-term economic benefits as well maximizing the available resources in the specific area.

In modelling a metric to define the 'best' and quantify it, our team has proposed a method of using Linear Programming, in the constraint of the provided data and pollution levels, to maximize the revenue generated of each of the presented option. We have then finally computed NPV (Net Present Value) for each of the option and compared the options based on highest NPV to figure out the 'best use' of the land.

II. PROBLEM INTERPRETATION

With the upsurge of populations in the recent century, land has become a valuable and scarce resource. Often, it's use is unmonitored which results in the valuable resources of the land being resources because of unplanned use. Therefore, we hope to make a mathematical model to define what the 'best' use of land might be to aid decision makers be confident about their choice in the final use of land.

III. ASSUMPTIONS & JUSTIFICATIONS

We have the following piece of land with following information.

1) The plot of land is modelled to have two separate, distinct elevation with 62% land being in 131 $metre$ height, and the remaining land being in $105m$.

Figure 1. Left, a satellite image of the parcel of land. Right, location of the parcel of land. (Shaded region.)[1]

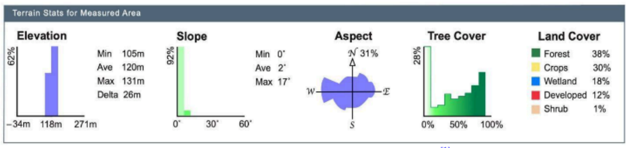

Figure 2. Terrain statistics for the parcel of land.[1]

a. This is assumed for the sake of simplifying the problem.

2) Short term benefits can be studied by comparing the number of people employed and the total revenue generated each year; however, long term benefit can be studied by looking at $CO2$ emissions of the options.

a. Since we want to make a metric considering long term as well as short term benefits, studying the revenue generated as well as environmental impact will give us a suitable model.

3) Revenue generated each year will be periodic in nature.

a. It is safe to assume that the revenue generated will depend on the time of the year, hence, we expect similar results to come out at a particular season each year. For example, revenue generated from skiing facilities will peak at winter and dip at summer, and this trend is there every year. 4) For comparison of revenue generated, we use NPV (Net Present Value)

b. NPV's are commonly used in literature to compare revenue generated for different investments.

IV. MODELING THE PROBLEM

As stated earlier, our model looks to maximize revenue generated for each option; given the constraints of land (topology, climate, aspect etc.) while minimizing carbon emissions. The maximum revenue generated for each option will be converted into an NPV value which will be compared to quantitatively define the 'best'.

A. Definition of variables

1) Names:

- Outdoor sports complex: O_1
- Cross-country skiing facility: O_2
- Crop farm: O_3
- Grazing farm/ranch: O_4
- Regenerative farm: O_5
- Solar Array: O_6
- Agri-voltaic farm: O_7
- Agritourist farm: O_8

2) Variables V_x (for x = 1,2,3,4,5,6,7) is for each option O_x

- Total cost of manufacture each option: C_x
- CO_2 emissions per year of each option: E_x
- Number of labours required per available of each option: L_x
- Available number of labours per each option: K_x
- Maximum revenue generated for each option per year: R_x
- Average revenue generated for each option per year: M_x
- Rate of return of investment for each option: r = 8%
- NPV value for each option: N_x

$$N_x = \sum_{i=1}^{10} \frac{M_x}{(1+r)^i} - C_x$$

- Time of year as a fraction of months: t
- Area given for each option in km^2: A_x

B. Algorithm to Find the 'Best Use' of Land

Our basic approach now is to take each option Ox and use linear programming to maximize the objective function, here being R_x.

For each case, our LP (linear program) will be subjected to the constraints of meeting the governmental standard for

a. Maximum CO_2 emissions
b. Number of people employed
c. Slope of land and effect on revenue collected
d. Number of similar options within 50 km radius
e. Cost of manufacture
   i. Cost of preparation of land
   ii. Cost of building infrastructure
   iii. Cost of maintenance
f. Number of relevant populations between ages $10 - 30$ years within 50 km radius (for skiing and outdoor sports facility only)
g. Number of tourists visiting Northern New York.
h. Specifics related to option

Finally, we'll take the optimized LP, giving us R_x to compute the average revenue generated, M_x of each option O_x.

Consider for each O_x, the value of R_x. For a 12-month cycle of a year, we supposed that the revenue generated will be given by the following periodic curve with a period of 12 units. If time t = 0 is peak summer, and t = 12 is peak summer of the next year,

$$M_x = \frac{\int_0^{12} R_x \times \left(\frac{\pi}{12} t\right) dt}{12}$$

Computing the result gives,

$$M_x = \frac{1}{2} \times R_x$$

Using this M_x value for each O_x, we compute N_x. Finally, the option, O_x, with the highest value of N_x will be the option that is best.

C. Adjustments to the algorithm

Instead of taking the option O_x with the greatest N_x, we can take the top three options with the highest N_x value and in turn make an LP constraining the areas A_X for these options.

This will give us an idea of how the total area $3km^2$ can be divided among the top three options to maximize our revenue, while also making the best use of the land.

V. CASE APPROACH

We consider the case for a crop farm. We take three crops, tomato, cabbage, and orange.

If T, C, O = Total area of Tomato, Cabbage, Orange farming,
$P(x)$ Profit per \$ unit area,
$L(x)$ Number of labours per unit area, then

$$P(T) = 109 \qquad L(T) = 6$$
$$P(C) = 90 \qquad L(C) = 4$$
$$P(O) = 115 \qquad L(O) = 8$$

Then, suppose we have a maximum labour force of 500 people. And we have a maximum area of 100 units,

Now, we need to maximize:

Revenue generated R_3 = $109T$ + $90C$ + $115O$ subject to:

$T + C + O \leq 100$ (Land)
$6T + 4C + 8) \leq 500$ (Labour)
$T \geq 0$ (non-negativity)
$C \geq 0$ (non-negativity)
$O \geq 0$ (non-negativity)

Then, solving this linear program using a simple tool,

We get,

$$T = 50$$
$$C = 50$$
$$O = 0$$

Giving a maximum $\boldsymbol{R_3}$ = \$**9950**

Computing $M_3 = \frac{R_3}{2}$ = \$4975

Hence,

$$N_3 = \sum_{i=1}^{10} \frac{M_3}{(1+r)^i} = \sum_{i=1}^{10} \frac{4975}{(1+0.08)^i} = 33382.65$$

Doing similar for other options will give us a N_x which can be compared.

VI. IMPACT ANALYSIS OF MICRON TECH. INC.

In October 2022, it was announced that Micron Technology, Inc. will build a very large semiconductor fabrication facility (fab) in Clay, NY, USA, a town just north of Syracuse, NY. It was also reported by news outlets that "If fully built, the fabs could employ up to 9,000 people making an average of $100,000 each year. They would create some 40,000 other jobs among suppliers, construction firms and other businesses. The new plant will directly support 9,000 jobs and create nearly 40,000 additional jobs.

Changes to the metric:

To consider how the introduction of this fab will affect our metric, we can look at the data from bureau of statistics of the number of people employed in a certain salary range.

We can look at cases, analysing how the establishment of the fab would affect each option.

For all options, it is safe to assume that introduction of the new fab will raise the cost of each labour, consequently adding to the initial cost. Because the number of labours in a specific place is somewhat constant, they will have alternatives to work on either fab or our option. So, because the demand of labour is higher, each option needs to compete the existing market by raising the pay of each labour, in turn increasing the cost of manufacture.

For options like O_1, O_2 and O_8, which rely on customers coming to the specific location itself, the introduction of the fab might be beneficial because this fab will produce 9000 high paid employees, who can come to these options to spend money, in turn raising the revenue generated.

VII. MODEL SUITABILITY

Our presented model is a simple model, that optimizes the revenue generated for each option using LPs and uses NPVs to compare the options. Because NPV's are a standard of comparison, and our algorithm presented is straightforward, with the right amount of data, we predict that using this algorithm would help us find the "best" use of land in all other environments presented too.

VIII. CONCLUSION

This model significantly improves the usage of land to optimize the revenue given the topography, climate, and nearby population. Taking into consideration the carbon emission and environmental impacts, it serves as a simplified approach to sustainable planning. While our model is specific to a land in Syracuse, NY and has only taken a few parameters, a similar approach with more parameters in climate, topography, and human population will yield an even more precise and accurate planning. We have sent our model in the form of a suggestion letter to the local government to inspire a sustainable land usage.

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