Letter to Decision Makers

Greetings, Community Planning Committee.
I'm writing to voice my support for the ideas for an agrivoltaic farm and agritourism centre in our neighbourhood. I am enthusiastic about the opportunities these solutions present since they could make a beneficial impact on our community in a variety of ways.

First off, an agrivoltaic farm would be a creative and ecological way to improve the production of local food. We could boost community access to fresh, locally farmed produce while also lowering our carbon footprint if we combined agriculture with solar energy generation. Also, the project would promote local economic growth and provide up job prospects.

An Agritourism Centre would also be a fantastic way to promote and highlight the distinctive agricultural and cultural heritage of our community. It might become a tourism attraction, giving travellers a chance to get up and personal with sustainability, nature, and agricultural life.

I am aware that there might be obstacles to get over, such finding funds, managing zoning laws, and winning over the neighbourhood. The advantages of these options, in my opinion, exceed any potential drawbacks by a wide margin. We can make these solutions a reality and build a better future for our neighbourhood and the environment by banding together as a community.

In FLP, we frequently have several goals to achieve, and each goal may have a few criteria attached to it. We can locate the best solutions that meet all the requirements at once with the aid of NSGA-II. In the instance of the agritourism facility and solar farm, we had several goals that we wanted to maximize, including the project's net present value (NPV) and social benefit (SB). Each objective was also subject to several other criteria, such as building costs, anticipated agritourism centre revenues, and project-related environmental impacts. Prior to using NSGA-II for FLP, we had to specify the goals. We then defined a fitness function that assessed the quality of each prospective solution using these goals and standards. The performance of each solution was assessed using this fitness function using the NPV and SB values as well as the numerous criteria related to each target. Our fitness function was created, and then we used NSGA-II to provide a collection of Pareto-optimal solutions. The optimal trade-offs between the various objectives and criteria were represented by these solutions. These answers were then used in our decision-making process for the project.

Overall, NSGA-II was a helpful tool for us in our analysis of the agritourism centre and solar farm project from several angles. We were able to reach a more well-rounded and educated judgment by utilizing FLP approaches like NSGA-II.

Best Regards,
IMMC Team

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1 Introduction

1.1 Background

City planning involves many stakeholders, each with different objectives and interests. When an opportunity to redevelop a plot of land arises, the decision to do so and commit resources will be a matter of contentious debate. The laborious and time-consuming process of determining the 'best use' of the land would ideally ensure that the land is used productively, safely, and done so for the benefit of the community. Among the factors to consider are economic, social, environmental, and social concerns, each important and require careful consideration. As is often the case, compromises and trade-offs will be inevitable, giving rise to conflict. Considering current and future needs of the community and how they can be met, city planners and other decision makers require mathematical models and other methods of evaluating current trends and predict future ones.

In Upstate New York, approximately 50 km north-west of Syracuse, in Cayuga County, there is an undeveloped parcel of land of approximately 3 km^2, which is being developed using optimal land use planning. Our task is to develop a model to determine which of 8 choices would be the best use of this land. Decision makers have proposed the following options for consideration: 1) Outdoor sports complex, 2) Cross-country skiing facility, 3) Crop farm, 4) Grazing farm/ranch, 5) Regenerative farm, 6) Solar array, 7) Agrivoltaic farm, 8) Agritourist centre.

1.2 Problem Restatement

Breaking the problem down into simpler parts, we must:

1. Define best use.
2. Define parameters to find the best use and their weightage, and then construct a model based on it.
3. From our opinions, find the (at least 2) facilities, then use our model to see which is the best.
4. Evaluate the effectiveness of the model.
5. Evaluate the effect of a nearby semiconductor fabrication facility on the model.
6. Evaluate how appropriate the model would be in a different location.

1.3 Basic assumptions and Justifications

1. On this piece of land, a maximum of 3 facilities can be built.

Justification: The area of this piece of land is around 3 square kilometres. We assume that each facility will take a minimum of 0.5 square kilometre and maximum of 1.5 square kilometres, the maximum total number of facilities will be 3, each with an average area of 1 square kilometres.

2. No local opposition for any of 8 options.

Justification: Not in my backyard syndrome (NIMBY), which is local opposition to proposed developments in the local area, is unlikely to have any tangible negative impacts on the feasibility. It is expected that few residents will be directly impacted by increased traffic, light pollution, noise pollution and other environmental or economic disturbances caused by construction. Conversely, infrastructure projects will bolster local economies through indirect job creation and population growth, bolstering businesses in the region and local enthusiasm for such construction projects.

3. Only residents within an hour of travel by car would benefit from these facilities

Justification: Since frequent commutes will not be necessary, unless directly employed, these facilities are considered non-essential. It is assumed that residents in the region will voluntarily commute longer distances on a less frequent basis. Increased productivity will likely result in economic benefits for residents, including those with no intention of visiting for work for leisure. For example, residents in Upstate New York will receive local agriculture products, reducing transportation costs for said products. As a general assumption, residents in each county's largest city with a commute of more than hour to the location will have negligible benefits from each facility.

4. There will always be demand for jobs in the region

Justification: Recent unemployment figures show that the unemployment number in New York is 883908. Demand for jobs would likely exceed this with the influx of immigrants and out-of-state workers who are looking for jobs. Since it is not expected that the land would host a significant number of highly skilled workers, it is assumed that these jobs will be filled. Also, there are always people leaving their jobs due to unsatisfactory conditions or being sacked each day so the number will always be >0 if the number of people in New York is >0.

5. No major disruptions or unforeseen disasters

Justification: Disruptions will include any unforeseen circumstance that affects the region/state/national/global level. Such disruptions may include a financial recession, natural disasters, global pandemics, civil unrest, and disruptions to local infrastructure. It may also constitute future technological advancements and change in policies and regulations. Such disruptions are difficult to predict and model and would likely affect all types of facility built in the land. It is assumed that the possibility of a such a disruption will have negligible effects on city planning policies specific to the region.

6. Economic impacts, profits and revenue are more important than social or environmental impacts.

Justification: It is assumed that economic benefits will indirectly support local efforts to tackle social and environmental concerns. By spurring economic growth in the region, the region attracts new businesses and investment, elevating economic productivity for all residents, regardless of direct implications of a facility on the lives of individual residents. With new investment in local businesses, the increased tax revenue collected by the local government will be distributed across social and environmental government initiatives.

General Definitions

1. Land: 'Land' will be used in this paper to refer to the 3 square kilometres of land in Upstate New York as defined in the IMMC problem statement
2. Facility: The term 'facility' will be used in this paper to refer to any of the 8 possible considerations as outlined in 1.1.
3. Economic impacts: Economic impact will come in different forms. Expenses associated with the construction of the facility and operating expenses will be reflected in the model. Net-Present-Value (NPV) will be used to evaluate the Return on Investment (ROI). Also considered economic impacts and factors to be considered are lost productivity and unemployment rate. Indirect economic effects from increased productivity and tourism are used to evaluate the total economic impact of a project.
4. Social impacts: Depending on the type of facility built, residents will feel a tangible impact. Large, impressive projects may instil a sense of pride among residents as such projects represent an improvement in local amenities and facilities. Facilities can also improve the quality of life through

provision of amenities such as energy, food, or water, or provide employment opportunities, which provides livelihoods for the unemployed. Facilities built can provide educational opportunities or promote a change in perception towards sustainable practices and green technology, providing societal benefits.

5. Environmental impacts: Greenhouse emissions and overall carbon footprint will defer between the types of facilities built. Especially with regards to agriculture, certain types of produce will require varying amounts of natural resources and inflict an array of environmental effects.
6. Best use: The term 'best use' as defined in this paper will be a trade-off between the following metrics. (1) The most benefit for the surrounding region (the region an hour or less to the land by car) in the form of economic, social, and environmental benefits. (2) The most favourable economic, social and environment impacts for the surrounding region. Both metrics will be evaluated with an appropriate weightage, and the short- and long-term effects. The facility with the 'best use' will ideally maximise benefits, while minimising unfavourable outcomes.
7. Short-term: 'Short-term' will refer to costs and expenses that are not expected to last longer than the construction duration, such as lost productivity. Additionally, it will include expenses that are usually incurred only once, such as the cost for construction for a facility.
8. Long-term: 'Long-Term' will refer to costs and expenses that are incurred over the duration that the building is operating under normal conditions. Economic expenses will include maintenance, operating expenses, and Net-Present-Value (NPV). Social benefits and environmental impacts will be considered using the same duration.
9. Best crops: The metric used to determine the best crops to use will be restricted to the ranking of crops based on the market share of crops produced for the State of New York, the associated cost and profits and certain environmental impacts.
10. Local Area: Local will comprise of the population of the surrounding counties of the land. The counties considered are chosen based on the duration of travel from its largest city. Syracuse, Onondaga County, for example, to the land takes approximately 47 mins. Counties that fulfil these criteria are Wayne, Cayuga, Seneca, Onondaga, and Oswego counties.

1.4 Variables

Best crops variable

Variable	Definition
A_{GHG}	Greenhouse gas emissions per 1000kcal (kgCO_2 per 1000kcal)
A_{Eutro}	Eutrophying emissions per 1000kcal (gPO_4 per 1000kcal)
A_L	Land use per 1000kcal
A_W	Scarcity-weighted water use per kilogram ($liters$ per kg)
W_{GHG}	Weightage of Greenhouse gas emissions in the total environmental score
W_{Eutro}	Weightage of Eutrophying emissions in the total environmental score
W_L	Weightage of Land use in the total environmental score
W_W	Weightage of Water use in the total environmental score
W_{env}	Weightage of environment in total score for crops
P_C	Profits Per acre($) for each crop
W_P	Weightage of profits in total score for crops

Economic benefits variable

Variable	Definition
NPV_f	Net present value of a facility f
FV_{ft}	Future Value which is net cash flow of a facility f at year t
t	Number of years passed after the facility is built and starting to operate
i	Discount rate or expected annual return for each facility

Social benefits variable

Variable	Definition
SB_f	Social benefits value for facility f
SI_f	Social interaction value for facility f
SS_f	Salary benefits value for facility f
P_f	People engage in activities in a facility f
$M_{interaction,f}$	Magnitude for social interaction in a facility f
$T_{interaction,f}$	Duration for social interaction in a facility f in hour in one year
W_f	Number of workers working in a facility f
$M_{salary,f}$	Magnitude for salary benefits value for average salary of workers in a facility f
$T_{salary,f}$	Duration of workers working in a facility f in hour in one year
SB'	Total social benefits score of a facility, obtained by normalising social benefits value of a facility to the range between 1 to 10.

Facility Location Problem variable

Variable	Definition
i	Possible location
N_f	Number of possible facility locations

X_i	Binary Variable: 1 if facility selected, 0 is not selected
NPV_i	Potential profit obtained from if i is selected
S_i	Potential social score obtained from if i is selected

Productivity Index variable

Variable	Definition
PI_f	Productivity index of a facility$f$
C_f	Construction cost of a facility f
U	Unemployment rate
$Area_f$	Total area of a facility f that must be constructed.

2 Development of Model

2.1 Economic benefits

2.1.1 NPV for possible facilities

The first factor we choose to be part of our model of determining the best facility is the economic benefits which is the Net Present Value (NPV) of a facility. NPV is an extremely significant factor that would largely influence the results of our model. In the area of doing business, especially when investing in a project, in this case, building facilities on a piece of land, NPV would foreshadow the economic results or status of the project in the future. Thus, NPV will determine the success rate of the project. When NPV is compared across facilities, we would observe the future monetary value of our business. To build a facility, meticulous plan is required. This is because the project of building a facility takes very long time. The project period can range between 2 to as many as 20 years. Hence, by using NPV as a factor to decide, the results of the model would assure the investor that the project they will be pursuing will grant them a fair degree of economic benefits.

Data

facility	Annual Profit ($)	Annual Revenue ($)	Annual operating expense ($)	Initial invested money ($)
Sport Complex	305208	1129386	160000	1600000
Skiing facility	2000000	10000000	200000	25000000
Grazing farm	40000	225000	28720	320000
Regenerative farm	22781	354000	124000	698082
Agrivoltaic farm	35491	432000	143600	879546
Agritourist centre	8162	50230	7550	94267

Model for NPV

To determine the economic benefits of a facility, we use the formula of Net Present Value (NPV). NPV is all value of net future cash flow over a period of an investment discounted to the present. This is to determine whether the project or in this case the facility is worth investing. NPV is today's value of the expected future value (net cash flow of a particular year ahead) subtracting today's value of invested monetary value.

Calculating NPV is the reverse process of determining the future value given that the expected annual return rate is constant. For example, if today's value is $100, and the expected return rate in 20%, the future value a year later will be $100 * 120%, which is 120. If the invested monetary value is $80, the net future value will be $120-$80 = $40. Thus, by reversing the process, present value will be calculated from the summation of future value from each year in the future.

In our model, we calculate our NPV using future present value, which will be the same for each year, for 5 years period after the facility is built.

$$Future\ value\ =\ \text{Average revenue of a facility annually} - \text{operating or maintenance expense.}$$

For expected annual return rate, i, we calculate using the annual profit and revenue for each facility.

$$i\ =\ \frac{average\ annual\ profit\ of\ a\ facility}{average\ revenue\ of\ a\ facility\ annually\ -\ average\ annual\ profit\ of\ a\ facility}$$

NPV for each facility:

$$NPV_{\ f}\ = \sum_{t=1}^{5} \frac{FVt}{(1+i)^t} - initial\ invested\ money\ \text{When}\ t = 1, 2, 3, 4, 5$$

After obtaining NPV value of each facility in $, economic benefits score will be given to each facility by considering the position where NPV of a facility is when compared to NPV of other facilities. Normalisation to range 1 to 10 inclusive will be our method of giving economic benefits score. Normalised score of 1 indicates the best worst economic score, and 10 indicated the best economic benefits score.

Normalising NPV to give a score:

$$NPV' = 1 + \frac{\left(NPV_f - \min N\ PV\right) \times 9}{\max N\ PV - \min N\ PV}$$

Result

Facility	Economic benefits score after normalising NPV
Sport complex	10.000000
Skiing facility	7.354295
Grazing farm	5.578704
Regenerative farm	5.605695
Agrivoltaic farm	5.520988
Agritourist centre	1.000000

2.1.2 Best Crops

We found that apple, tomato, and tomato are the best crops that suit the climate, as well as are the crops that are in relatively high demand in the market. For animal, we found that beef cow is the most popular and suitable animal to do a farm or a grazing farm. (kaggle, 2023)

To optimise land use for crops agriculture, we would determine the best crops amongst apple, potato, and tomato to divide farmland and allocate an area for a specific crop. As the total area of our average farmland will be 200 acres, the best crop will be given 100 acres, the second-best and third-best crops will be given 50 acres of land each

Data is in appendix*

Environmental impact factors:

Greenhouse gas

Greenhouse gas emitted will be one of the factors that will be considered to determine the environmental impact. Due to our world's climate change, every action must be taken in the most calculated manner possible such that it would have the least negative impact to our environment. Any action that contributes to a negative environmental impact should be avoided. This is justified by the importance of the climate to growing crops. While a drastic temperature fluctuation would greatly affect the yield of the crops on this piece of land, this piece of land is situated within temperate marine climate zone. In temperate marine climate, there are not too many extremes. There is a snowy season; however, it does not last that long.. Thus, choosing to grow crops that will result the least greenhouse gas emitted will the benefit the farm in the long run.

Eutrophication emissions

The eutrophication emissions of each crop refer to amount of excess nutrients release to surrounding by the crop. This affects pollute ecosystem. Eutrophication is a serious environmental concern. When the eutrophication emissions per 100kcal is extremely high, there is a high likelihood that the water quality will be greatly compromised, as well as it would result in the depletion of dissolved oxygen in water bodies. This factor is imperative to minimise the detrimental effect that could be inflicted to the surrounding soil. Thus, the Eutrophication emissions will be added to the environmental impact.

Land use

Land use is one the factors as land is a limited resource on the earth. Even though we have been given a designated land area to build a facility or a farm, we still need to optimise the land for the maximum benefits from the crops. The wiser usage of land would secure other benefits as well. Thus, land use to grow a specific amount of crop would be considered as an important factor for environmental impact.

Water use

The same as land, water is also a limited resource on this earth. About 2.5% of the water on the earth is fresh water which is necessary for agriculture. Moreover, to minimise the cost of water use, the crop which requires the least amount of water would be a better alternative. Thus, with the stated reasons, water use will be considered as the last factor which contributes to the environmental impact.

Profit factor:

Gross income per acre ($)

Gross income per acre is defined as money that can be made from harvested an acre of a specific crop. To put it simply, it roughly determines how profitable the crop is. The use of economic means to evaluate the suitable crops can be seen predominantly in many farm businesses. For a farmer, one criterion for the best crop would be how much money can be made from the crop. It is a very reasonable decision to use profitability to determine the best crops.

Assumptions and justifications

1. Weight of the Profits is more important compared to the environmental effects to the Target.

   Justification: Cayuga already has environmental policies in place. Also, this paper is mostly catering to business planners.

2. All roofs of all facilities would be covered by solar panels.

Justification: This would eliminate the option of having a solar array and potentially the option of having a normal crop farm. It would ensure that we meet the 'best use' criteria. Having a dedicated solar array in a climate this land is in is not efficient.

3. An agritourist centre will work best when paired with farms and vice versa

Justification: Agritourist centres will attract more people when there is a legitimate farm nearby as they can show the things they mention. Likewise, farms will gain money from letting agritourist centres use their farms.

Model to decide best crop.

In our model, firstly, we calculate environmental score. The score for a specific environment aspect is obtained by normalising each environment data for the above table to a range of 0 to 1 inclusive. Before each specific score is added together, the score will be multiplied by the weightage given to each aspect of environmental impact. Then, score for each aspect of environmental impacts will be total up to be the environmental impact score for each crop.

Secondly, profit score is obtained by normalising the gross income per acre ($) to a range of 0 to 1 inclusive. This is to make environmental impact score and profit score the same scale, to total the score later.

Lastly, overall score is determined by subtracting environmental score from profits score. This is because profits score is positive and environmental score, which is environmental impact, is negative. When subtracting, as profits is more important than environmental value, profits score will be weighted higher that the environmental value.

Equations

Environment Score calculations:

$$GHG\ Score = \frac{A_{GHG} - \min A_{GHG}}{\max A_{GHG} - \min A_{GHG}} \times W_{GHG}$$

$$Eutrophying\ Score = \frac{A_{\mathrm{Eutro}} - \min A_{\mathrm{Eutro}}}{\max A_{\mathrm{Eutro}} - \min A_{\mathrm{Eutro}}} \times W_{\mathrm{Eutro}}$$

$$Land\ Use\ Score = \frac{A_{\mathrm{L}} - \min A_{\mathrm{L}}}{\max A_{\mathrm{L}} - \min A_{L}} \times W_{\mathrm{L}}$$

$$Water\ Use\ Score = \frac{A_{\mathrm{W}} - \min A_{\mathrm{W}}}{\max A_{\mathrm{W}} - \min A_{W}} \times W_{\mathrm{W}}$$

where W_{GHG} = 0.4, W_{Eutro} = 0.3, W_{L} = 0.2, W_{W} = 0.1

$$Environment\ Score = GHG\ Score + Eutrophying\ Score + Land\ Use\ Score + Water\ Score$$

Profit Score Calculations:

$$Profit\ Score = \frac{P_C - \min P_C}{\max P_C - \min P_C}$$

Final Score Calculations:

$$Final\ Score = Profit\ Score \times W_p - Environment\ Score \times W_{env}$$

where W_p= 1.2 and W_{env} = 0.2

Result:

Product	Final score
Beef cow	–0.133681
Tomatoes	0.986133
Potatoes	1.056658
Apples	1.196521

Conclusion

In conclusion, we can see from the result table that the best crop with highest final score is apple, the second-best crop is potato, and the third-best crop is tomato. Hence, apple will occupy a maximum of 100 acres of farmland, and tomato, together with potato, will occupy a maximum of 50 acres of farmland each.

The reason why beef cow has negative score is because the yield it gives out is being overcome by its negative environmental impact. Therefore, if we consider in a perspective of an environmentalist, we will agree that growing beef cow is not a very environmental-friendly act to do. Despite that, beef cows are still the best animal to do grazing agriculture.

All in all, this model is built to briefly determine how the farmland should be divided based on the score of each crop.

2.2 Social benefits

Social benefits score is another main factor to determine the 'best' facility. When building a facility, apart from the economic reward received, the investor should consider the impact of a facility is terms of people affected. We assume that the community leader would always hope for the best for the people in the community. Thus, by ensuring the society will receive a positive influence from a facility would be a reasonable decision to make.

For our model, we categorise social benefits value of a facility into 2 separate categories: Social interaction value and Salary benefits value.

Social benefits factor:

Social interaction value

We choose social interaction to generally transform the activities carried out in a facility into a numerical value for better comparison and calculation for overall score. Social interaction is defined as average amount of activities carried out in a facility because of the gathering of people. The more social interaction value means that more people are active in a facility. This indirectly contributes to more profit made from the facility, as more people are using it. As a person who aims to further develop the community, a community leader would hope that facilities-built grant sufficient access to people in the community. Hence, we use social interaction value as a factor to calculate social benefits score to define the best facility.

Salary benefits value

Another implementation of building a facility is that jobs will be created. People who work in a facility would receive their salary to provide for their families. Not only will the facilities provide jobs for unemployed city members in the area, but it will also help improve their lives' quality. Therefore, it can be considered as a happiness index of workers in a facility. Thus, salary benefits value will be the second factor to determine the social benefits score.

Both factors are equally important as we must maximise the social benefits score by looking at both beneficiaries. Workers receive money from providing service and the people visited receive the service from the worker after paying them.

Model for social benefits score

Social interaction value data

Facility	**Average People affected**	**Magnitude**	**Duration (hour) in one year**
Sport complex	109	2	2600
Skiing facility	109	2	516
Grazing farm	55	1	1300
Regenerative farm	55	1	1300
Agrivoltaic farm	55	1	1300
Agritourism centre	109	2	1300

Notes:

1. The duration of each facility is an estimated value of total operating hour of a particular facility in a year.
2. Average people, for sport complex, skiing facility and agritourism centre, is determined by people visiting a facility within a period of 1 hour and 5% of nearby neighbourhood population.
3. Average people affected of farms is determined by people affected by the products of the farm. It includes people who buy is, sells it or eat it. We set the number of people affected to be 2.5% of nearby neighbourhood population.

Salary benefits data

Facility	Average annual salary of jobs in a facility ($)
Sport complex	59840
Skiing facility	62572
Grazing farm	61875
Regenerative farm	61875
Agrivoltaic farm	61875
Agritourism centre	88900

Equating magnitude of the salary in each facility

We define magnitude of salary of each facility by giving it a normalised value of itself, with the range from 2 to 4 inclusive.

$$M_{salary,f} = 2 + \frac{(S_a - \min S_a)\times 2}{\max S_a - \min S_a}$$

Where S_a is an average annual salary of workers in a facility

Second salary benefits data with magnitude

Facility	Average number of workers in a facility	Magnitude of average salary in a facility	Duration (hour) in one year
Sport complex	42	2.000000	2080
Skiing facility	42	2.188025	516
Grazing farm	25	2.140055	2190
Regenerative farm	10	2.140055	2190
Agrivoltaic farm	10	2.140055	2190
Agritourism centre	15	4.000000	2190

Equation for SB_f:

$$SB_f = SI_f + SS_f$$

Find SI_f:

$$SI_f = \frac{P_f \times M_{interaction,f} \times T_{interaction,f}}{1000}$$

Finding SS_f :

$$SS_f = \frac{W_f \times M_{salary,f} \times T_{salary,f}}{1000}$$

Equating magnitude of the salary in each facility

We define magnitude of salary of each facility by giving it a normalised value of itself, with the range from 2 to 4 inclusive.

$$M_{salary,f} = 2 + \frac{(S_a - \min S_a) \times 2}{\max S_a - \min S_a}$$

Normalisation of Social benefits to assign score.

To evaluate overall score in the very last step of deciding top 3 facilities, the scores are made into the same scale as other main factors. This is achieved by normalising the social benefits value into a range of 1 to 10 inclusive (where 1 indicates the worst social benefits value and 10 indicates the ideal social benefits value of a facility). Then, we would give out scores accordingly.

$$SB' = 1 + \frac{(SB_f - \min S\,B) \times (9)}{\max SB - \min SB}$$

Results

Facility	Social benefits score (After normalised)
Sport complex	10.000000
Skiing facility	1.599944
Grazing farm	1.000000
Regenerative farm	1.000000
Agrivoltaic farm	1.000000
Agritourist centre	5.281286

2.3 Productivity Index

In this paper, Productivity Index (PI) can be defined as a metric used to compare the economic impact of construction cost of each facility for the local economy. Taking into consideration the area of the facility and construction time, the PI equation will indicate the facility with the most indirect benefit for the local economy.

Assumption

1. Cost overruns are not expected to happen

Justification: Cost overruns are often due to unforeseen circumstances such as design changes, delays and disruptions, poor management, and others. Due to the unpredictable nature of such an occurrence, cost overruns will not be factored into construction costs.

2. Economic contribution of an agritourist centre should be evaluated with another facility for the purposes of PI.

Justification: An agritourist facility will only be attractive as an option for visitors if there is some sort of farm infrastructure already present, either a crop farm or grazing farm. Without so, the centre would not be an efficient use of resources. Thus, by combining the centre with other facilities, the PI can be evaluated at a fairer level. For other intents and purposes, the agritourist centre will be evaluated separately from other facilities. PI of the agritourist facility will also be presented.

Productivity factors:

Construction Cost

Construction cost for each facility is indicative of the impact on economic productivity for the region A large construction costs presents opportunities for job creation and local sourcing of materials, which drives the local economy. New construction jobs increase employment and subsequently median income. A large product would ideally use local contractors and suppliers, ensuring that a part of the construction cost is directly invested into the economy. It is assumed that the cost for the facilities will not be financed using debt.

Unemployment Rate

During times of low economic productivity and high unemployment rate, the demand for high spending for the benefit of local businesses and residents is the highest due to the potential of such projects in increasing economic activity. Conversely, when unemployment rates are low, investing in the local economy to boost job creation is less of a priority.

Area

Different facilities will vary in the amount of land required to build the facility. It is necessary to compare the efficiency of funds used to construct a facility using the area it occupies to make a fairer model. A project may have a high construction cost but erected on a much larger area, reducing the overall benefit it has on the economy due to the potential uses of the extra land used. Using the area to calculate lost productivity, a comparison can be made between projects with vastly different construction costs and area usage to evaluate the efficiency of funds used for the economy.

Duration

Duration will determine how investment in the economy is distributed over time. Projects with quicker construction times will be investing costs into the economy more efficiently.

Construction Cost, Area and Duration, values data

*Note that Agritourist Centre is abbreviated to AC

Facility	Cost	Area (km^2)	Duration (years)
Sports Complex	32000000	1.000	3.0
Skiing Facility	20000000	1.500	3.0
Grazing	320000	0.809	1.0
Regenerative	750000	0.809	1.1
Agrivoltaic	879546	0.809	1.1
AC + Grazing	414267	0.809	1.1
AC + Regenerative	844267	0.809	1.1
AC (with no other facility)	94267	0.005	1.1

Calculating Unemployment Rate

Labour force would comprise of the adult working population that resides in counties (Wayne, Cayuga, Seneca, Onondaga, Oswego) within an hour drive of the land as defined in 1.3. Used to calculate the labour force in the counties within an hour drive are the number of local employed workers and unemployed.

Labour Force value data

County	Employed	Unemployed	Labour Force
Wayne	41300	1800	43100
Cayuga	33700	1500	35200
Seneca	13900	600	14500
Onondaga	213800	8500	222300
Oswego	5010	2800	52900
Total for all counties	**352800**	**15200**	**368000**

Unemployment Rate = (Unemployed / Labour Force) * 100

Using the given values, the unemployed rate for the 5 counties is 4.13%

Equation for PI

$$PI_f = \frac{C_f \times U}{Area_f \times T_f}$$

In the equation, construction cost and unemployment rate are quantities that should be maximised for the highest PI score, indicating a significant contribution to the economy while constructing the facility. Area of the facility and the construction duration reduces the overall distribution of economic contribution over time and area, providing a metric with the same units that can be used for comparison between each facility.

Result before normalisation

Facility	Productivity Index
Sports Complex	44.057971
Skiing Facility	18.357487
Grazing farm	1.633793
Regenerative farm	3.481094
Agrivoltaic farm	4.082377
AC + Grazing	1.92280
AC + Regenerative	3.918631
AC (separate)	70.793399

Normalising the data

To evaluate each facility's PI score, the data are reconfigured to the same scale through normalising PI into a range of 1 to 10 inclusive. A PI score of 1 indicates the worst PI score, the least economic benefit for the local area over time and area, while a Pi score of 10 indicates the best PI score, the most economic benefit for the local area over time and area.

Result (AC is combined with other facilities)

Facility	Productivity Index score (after normalisation)
Sport complex	10.000000
Skiing facility	4.547817
Grazing	1.000000
Regenerative	1.391892
Agrivoltaic	1.51945
AC + Grazing	1.061311
AC + Regenerative	1.484712

Result (AC is separate from the other facilities)

Facility	Productivity Index score (after normalisation)
Sport complex	6.520818
Skiing facility	3.176317
Grazing	1.000000
Regenerative	1.240396
Agrivoltaic	1.318643
AC	10.000000

Conclusion

The sport complex and skiing facilities performed the best overall for PI, showing that such developments will give considerable economic advantages to the local area. However, such facilities are also incredibly expensive. When accounting for the fact that an agritourist centre can be separated from other facilities, it performed better than the sport complex due to its small footprint.

2.4 Best Facilities

Last step to determine the 'best' facility is to combine the score from 3 major factors, Economic benefits, Social benefits and Productivity index.

In the process of adding up the score, each score for each major factor will be given weightages. Economic benefits score is the most important indicator as it shows how profitable the facility is after built. In all businesses, money matters. Social benefits score will be the second of importance. As mentioned earlier that a community leader would hope. Lastly, the productivity index will be the last of importance as its value is the least tangible and the most indirect benefit.

Weightage for Economic benefits score = 0.5

Weightage for Social benefits score = 0.3

Weightage for Productivity index score = 0.2

Equation $Overall\ score\ = Economic\ benefits\ score\ \times\ weightage + \ Social\ benefits\ score\ \times\ weightage\ \ + \ Productivity\ score\ \times\ weightage$

Result

Facility	Final score
Sport complex	10.000000
Skiing facility	4.547817
Grazing	1.000000
Regenerative	1.391892
Agrivoltaic	1.51945
AC + Grazing	1.061311
AC + Regenerative	1.484712

Conclusion

2.5 Facility Locations

Assumptions and Justifications

1. P_i obtained from both facilities are the equal; Only i affects P_i

Justification: We are comparing the effect of locations on the facilities and thus having different values for P_i would cloud judgement and would not be necessary as this has been done in earlier parts of our model already.

2. $N_i = 3$

Justification: Referring to the 1st Assumption in section 1.3, there is a maximum of 3 facilities that can be built. Based on our model and research we recommend 2 facilities to be built. Including hybrid facilities. Mode of Facility Area is around half of the total land area, thus we decided to have 3 possible locations, 2 of which facilities will occupy and the 3rd location would be accommodated by the larger facility. (i.e. cross country skiing facility and agritourist centre).

Equations

Objective functions:

$$\max\ NPV_i = \sum_{i=1}^{N_f} NPV_i, i \times x_i$$

$$\max S_i = \sum_{i=1}^{N_f} SB_i, i \times x_i$$

Description

This is a Facility Location Problem (FLP) modelled as a multi-objective optimization problem using the NSGA-II algorithm. This is done using the Pymoo library. Each facility has its own associated profits and social score. The goal is to select a subset of facilities such that the profit and social score is maximized. The output of the model are the Pareto optimal sets which are then compared to give the best possible profits.

Conditions

Skiing facility

If skiing facility is selected the total number of facilities that can be built on this piece of land will decrease from 3 to 2 facilities.

Agritourist centre

If agritourist centre is selected, farm must be selected.

NPV of a farm

Only NPV of a farm will vary when place in different location. This is due to the geographic status of the location. This piece of land is situated in the northern hemisphere, hence north aspect will be cooler that the south aspect. There is a higher rate of evaporation of water from the soil of the south aspect location. The amount of water in the soil would affect the quality of the soil that contributes to the growth of crops. Hence, we assume that there will be higher yield which results in higher NPV is a farm is situated in an area that has north aspect as a majority. Additionally, there will be lesser yield of crops, resulting in less NPV when the farm is situated in an area that has south aspect as a majority.

Social benefits of a facility

We create gauge by stating that social benefits will directly be affected by internet accessibility. This is because less people will choose to come visit if they know that there is no mobile data to access the Internet in that area. Moreover, the absence of access to the Internet will cause the number of activities carried out in the area to decrease. The location where facilities are located will determine the change in social benefits of a facility.

Analysis

The calculated hypervalue for this model is a whopping 47.566. After conducting a sensitivity analysis, we found that our model is rather insensitive when we change crossover probabilities. This shows two sides. The good thing is that are model holds up quite well and provides optimal solutions. However, it also tells us that our model cannot be further optimised.

Computed Outputs

By comparing, the Pareto sets, we obtained Location X and Location Y as the best possible locations for facilities to be built. These are then plotted on the outline of the land using Matplotlib. The locations are represented as a point. The facilities would be built around these points, with the point being the heart of the facility.

3 Other problems

3.1 Task 3 - Adaptation of model

In October 2022, it was announced that a semiconductor fabrication facility would be built in Clay, NY, approximately 41 km from the undeveloped land was going to be built. Promising to employ up to 9000, each making an average of 100k annually, while creating an additional 40k other jobs among suppliers, construction firms and other businesses How would this impact our model?

Assumptions and Justifications

1) Employment for the fabrication facility will not primarily consist of Upstate New York, inclusive of the surrounding regional area around Clay, NY, USA.

Justification: With an average income of 100k, it is reasonable to assume that a considerable number of highly skilled workers will be needed to operate the facility. As such, these jobs, comprising mainly of these technical jobs, would likely be fulfilled with workers from out-of-state. Though it is expected that workers that did not originally originate from the community will choose to reside where they work, the number of workers that will choose to move in will be assumed to move into counties not considered in the local area as defined above.

2) A fraction of the 40k additional jobs created will boost local employment figures.

Justification: Since a fabrication facility of such a scale requires an array of specialised parts and equipment, most of these supplier jobs will be fulfilled with contractors from other states or imported from other nations. As such, residents, small businesses, and local contractors are unlikely to directly supply all the resources needed for the fabrication facility. The assumption made is that 10% of direct and indirect jobs created from the fabrication facility will comprise of workers living in the local area, considering that some local areas previously considered no longer falls within the one-hour travel duration to the fabrication facility.

3) Environmental effects are negligible

Justification: Local environmental regulations are in place, and proper management of waste materials from the fabrication facility are expected to be adequately disposed of to ensure the environmental conditions of the surrounding areas.

Factors

Using the same model, the primary change affecting the result of the model will be PI. Since PI, as defined in this paper, is a metric determining how useful an infrastructure project would be for the local community, having a large infrastructure project already being constructed will limit the economic output of another facility built with a high construction co

Unemployment Rate

As defined above, unemployment rate is a measure of local demand for jobs and economic productivity. This variable will likely decrease with local employment increasing when the fabrication facility is being built. Assuming 10% of jobs are given to the local area, the direct jobs added are 900 direct jobs, and 4000 indirect jobs.

New Employed, Unemployed, Labour Force values data

Employed	Unemployed	Labour Force
357700	10300	368000

Calculating the new Unemployment Rate

The new unemployment rate after the construction of the fabrication facility is 2.80%, a 1.33% reduction.

New Productivity Index score

Facility	Old Productivity Index	New Productivity Index	Percentage decrease (%)
Sport complex	44.057971	29.855072	67.763156
Skiing Facility	18.357487	12.439613	67.763156
Grazing	1.633793	1.107110	67.763156
Regenerative farm	3.481094	2.358899	67.763156
Agrivoltaic farm	4.082377	2.766347	67.763156
AC + Grazing	1.92280	1.302952	67.763156
AC	3.918631	2.655388	67.763156

Conclusion

The PI score shows that with reduced unemployment, the expected economic contribution for each facility reduces. For any major investment, the Productivity Index will provide some insight into the expected gain for the community in the local area. A major fabrication facility drastically reduces the need for other large and expensive infrastructure projects.

3.2 Task 4 - Adaptation of model

In December 2017, Singapore announced that it was going to consolidate all its ports into a Tuas megaport, closing the Pasir Panjang, Pulau Brani, Keppel and Tanjong Pagar ports. The Singapore government announced a Greater Southern Waterfront project to develop those lands. However, lets assume that this does not happen. The parcel of land specifically focused on here is the Pasir Panjang port, measuring 6.2km2.

Assumptions and Justifications

1. Skiing facility cannot be built in Singapore

Justification: The average temperature in Singapore is 27.8 degrees, which is not enough to support a skiing facility without lots of air conditioning, which needs a lot of electricity which costs a lot of money which will reduce the high profits of the skiing facility. Also, the slope in the new piece of land is not steep enough for a skiing route.

Major differences

1)Double land (6 km^2), 2) Flatter terrain, 3) Higher median income and population served, 4) Higher Temperature

Using the model, we can expect to see 1) Higher SB due to higher population, 2) Higher PI due to extra expense, 3) More choices to configure the land for FLP

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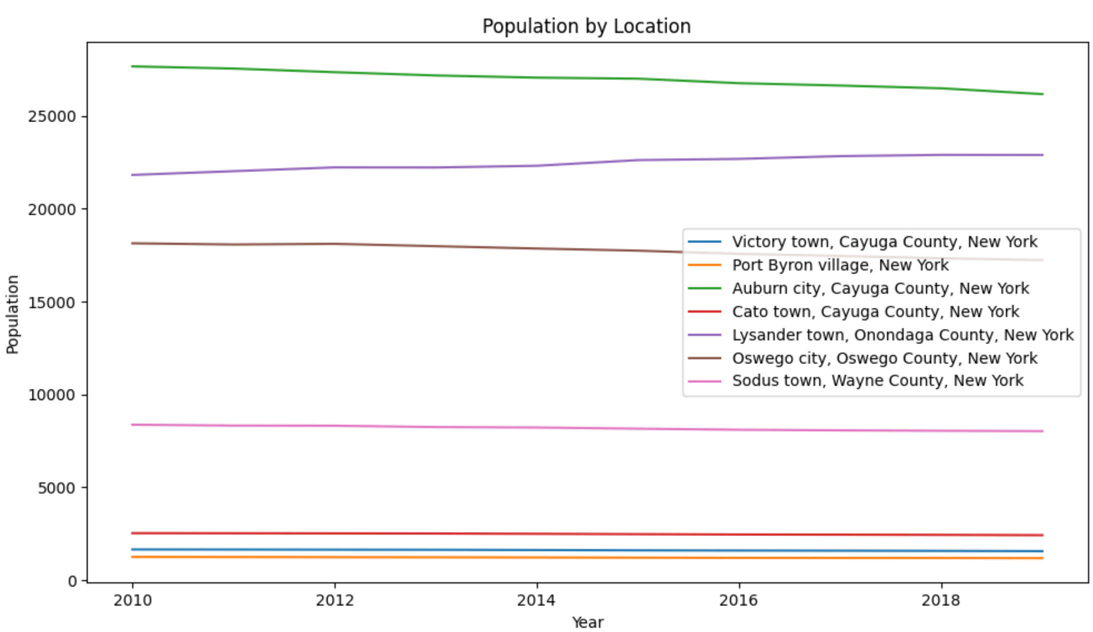
Appendices

Appendix A

population.py

```
import pandas as pd
import matplotlib.pyplot as plt

df = pd.read_csv("data/Demographics & Energy/population.csv")
df.rename( columns={'Unnamed: 0':'Location'}, inplace=True )

for i, row in df.iterrows():
    location = row[0]
    population = row[1:]
    population = [int(p.replace(",", "")) for p in population]
    plt.plot(range(2010, 2020), population, label=location)

plt.xlabel("Year")
plt.ylabel("Population")
plt.title("Population by Location")
plt.legend()
plt.show()
```

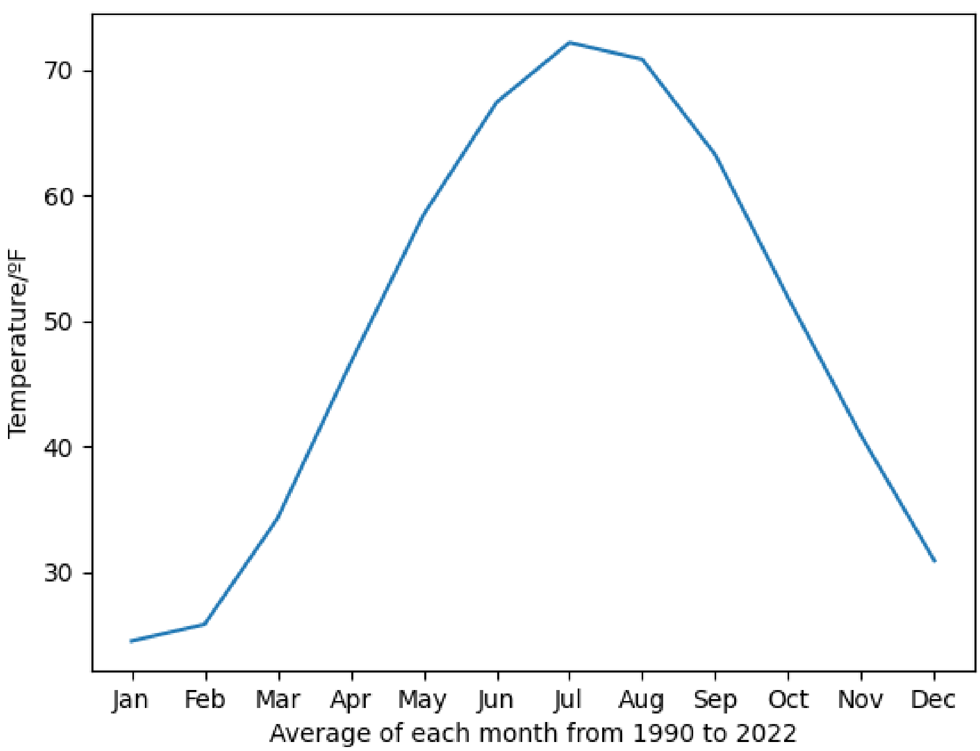
Output



temperature.py

```
import matplotlib.pyplot as plt
import pandas as pd

df = pd.read_csv("data/Demographics & Energy/temperature.csv")
df.drop(columns=['Year'], inplace=True)
df.drop(columns=['Annual'], inplace=True)

average = df.mean()

plt.plot(average.keys(), average.to_numpy())
plt.xlabel("Average of each month from 1990 to 2022")
plt.ylabel("Temperature/ºF")

plt.show()
```

Output



cropdecider.py

```python
import pandas as pd
import numpy as np

GHG_WEIGHT = 0.4
EUTRO_WEIGHT = 0.3
LAND_USE_WEIGHT = 0.2
WATER_USE_WEIGHT = 0.1

crops = pd.read_csv('data/Crop Data/Food_Production.csv', delimiter=',')
profits = pd.read_csv('data/Crop Data/foodreturns.csv', delimiter=',')
for index, crop in crops.iterrows():
    ghg_score = ((crop['Greenhouse gas emissions per 1000kcal (kgCO₂eq per 1000kcal)']-np.nanmin(crops['Greenhouse gas emissions per 1000kcal (kgCO₂eq per 1000kcal)']))/(np.nanmax(crops['Greenhouse gas emissions per 1000kcal (kgCO₂eq per 1000kcal)'])-np.nanmin(crops['Greenhouse gas emissions per 1000kcal (kgCO₂eq per 1000kcal)']))) * GHG_WEIGHT
    eutro_score = ((crop['Eutrophying emissions per 1000kcal (gPO₄eq per 1000kcal)']-np.nanmin(crops['Eutrophying emissions per 1000kcal (gPO₄eq per 1000kcal)']))/(np.nanmax(crops['Eutrophying emissions per 1000kcal (gPO₄eq per 1000kcal)'])-np.nanmin(crops['Eutrophying emissions per 1000kcal (gPO₄eq per 1000kcal)']))) * EUTRO_WEIGHT
    land_use_score = ((crop['Land use per 1000kcal (m² per 1000kcal)']-np.nanmin(crops['Land use per 1000kcal (m² per 1000kcal)']))/(np.nanmax(crops['Land use per 1000kcal (m² per 1000kcal)'])-np.nanmin(crops['Land use per 1000kcal (m² per 1000kcal)']))) * LAND_USE_WEIGHT
    water_use_score = ((crop['Scarcity-weighted water use per kilogram (liters per kilogram)']-np.nanmin(crops['Scarcity-weighted water use per kilogram (liters per kilogram)']))/(np.nanmax(crops['Scarcity-weighted water use per kilogram (liters per kilogram)'])-np.nanmin(crops['Scarcity-weighted water use per kilogram (liters per kilogram)']))) * WATER_USE_WEIGHT
    total_score = ghg_score + eutro_score + land_use_score + water_use_score

    crops.at[index, 'Environmental Score'] = total_score


"""
Beef, Apples, Potatoes, Tomatoes (Shortlisted due to climate conditions and demand)
Beef, Apples, Potatoes and Tomatoes are among NYC's top produce indicating demand. However,
They are not the topmost produce as the market is usually Saturated and has a lot of competition
by the most popular produce.
"""
selected = crops[(crops["Food product"] == "Potatoes") | (crops["Food product"] == "Tomatoes")|(crops["Food product"] == "Beef (beef herd)")| (crops["Food product"] == "Apples")]
profits['Environmental Score'] = selected.iloc[::-1].reset_index(drop=True)['Environmental Score']

ENV_WEIGHT = 0.2
PROFIT_WEIGHT = 1.2


for profit in profits.iterrows():
     profit_score = ((profits['Profits Per acre($)'])-np.nanmin(profits['Profits Per acre($)']))/(np.nanmax(profits["Profits Per acre($)"])-np.nanmin(profits['Profits Per acre($)']))
     profits['Profits'] = profit_score
     overall =  PROFIT_WEIGHT*profits['Profits'] - ENV_WEIGHT*profits['Environmental Score']
     profits['Final Score'] = overall

print(profits)
```

Output

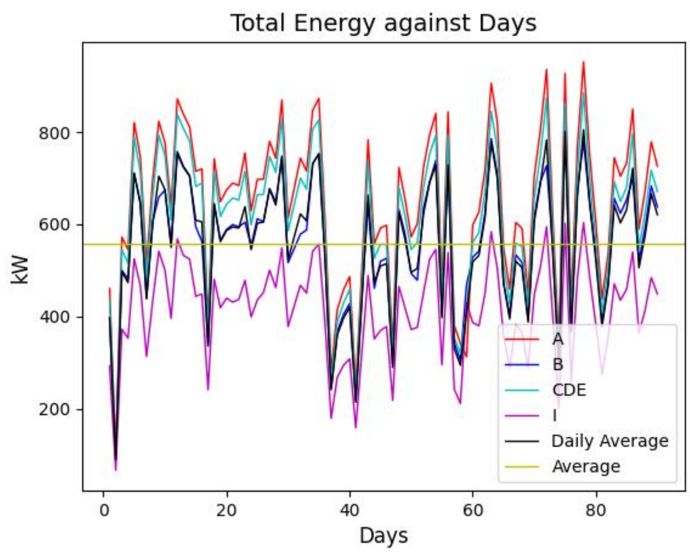
```
    Product  Profits Per acre($)  Environmental Score   Profits  Final Score
0      Beef                  200             0.668404  0.000000     1.336809
1    Apples                 2324             0.017396  1.000000     8.034793
2  Tomatoes                 2000             0.154079  0.847458     7.087818
3  Potatoes                 2075             0.013319  0.882768     7.088784
```

solar.py

```python
import csv
import matplotlib.pyplot as plt
import statistics

file_name = "data/Demographics & Energy/solarenergy.csv"

file = open(file_name)
file_reader = csv.reader(file)
dp = list(file_reader)

headers = dp[0]
dp = dp[1:]

# The 4 locations where solar panels were installed
A, B, CDE, I = "CWSS_BLK-A", "CWSS_BLK-B", "CWSS_BLK-CDE", "CWSS_BLK-I"
TIMEDATE, DP_LOCATION, DP_ENERGY = 0, 1, 2
TIME, DAY, MONTH, LOCATION, ENERGY = 0, 1, 2, 3, 4

processed_dp = []
for i in range(len(dp)):
    dp[i][DP_ENERGY] = float(dp[i][DP_ENERGY])
    dnt = dp[i][TIMEDATE].split()
    date, time = dnt[0], dnt[1]
    date = date.split("/")
    day = int(date[0])
    month = int(date[1])
    time = time.split(":")
    time = int(time[0])
    processed_dp.append([time, day, month] + dp[i][1:])

def filter_lst(subject, subject_value, lst):
    result = []
    for i in range(len(lst)):
        if lst[i][subject] == subject_value:
            result.append(lst[i])
    return result
```

```
# Filter data by locations
dp_A = filter_lst(LOCATION, A, processed_dp)
dp_B = filter_lst(LOCATION, B, processed_dp)
dp_CDE = filter_lst(LOCATION, CDE, processed_dp)
dp_I = filter_lst(LOCATION, I, processed_dp)


# UDF to retrieve the energy generated per hour
def hourly_energy_generated(lst):
    hourly_energy_per_day = []
    for month in range(lst[0][MONTH], lst[-1][MONTH]+1):
        dp_mth = filter_lst(MONTH, month, lst)
        for day in range(dp_mth[0][DAY], dp_mth[-1][DAY]+1):
            dp_day = filter_lst(DAY, day, dp_mth)
            hourly_energy = []
            for dataset in dp_day:
                hourly_energy.append(dataset[ENERGY])
            hourly_energy_per_day.append(hourly_energy)
    return hourly_energy_per_day


# UDF to calculate the total energy generated per day
def total_energy(lst):
    result = []
    for dataset in lst:
        result.append(sum(dataset))
    return result

# Retrieve maximum and total energy generated by location per day
A_hourly = hourly_energy_generated(dp_A)
A_total = total_energy(A_hourly)
B_hourly = hourly_energy_generated(dp_B)
B_total = total_energy(B_hourly)
CDE_hourly = hourly_energy_generated(dp_CDE)
CDE_total = total_energy(CDE_hourly)
I_hourly = hourly_energy_generated(dp_I)
I_total = total_energy(I_hourly)

DAILYAVERAGE_total = [(A_total[i] + B_total[i] + CDE_total[i]+ I_total[i]) / 4 for i in
range(len(A_total))]
o_average = statistics.mean(DAILYAVERAGE_total)
# Plotting Graphs of Maximum Energy (kW) against Days
# Setting up x-axis values
x_total = []
for i in range(len(A_total)):
    x_total.append(i+1)
print(o_average)
# Plotting a line for each location
plt.plot(x_total, A_total, color="r", linewidth=1, label="A")
plt.plot(x_total, B_total, color="b", linewidth=1, label="B")
plt.plot(x_total, CDE_total, color="c", linewidth=1, label="CDE")
plt.plot(x_total, I_total, color="m", linewidth=1, label="I")
plt.plot(x_total, DAILYAVERAGE_total, color="k", linewidth=1, label="Daily Average")
plt.axhline(y=o_average, color="y", linewidth=1, label="Average")



plt.legend(loc = 4)
plt.title("Total Energy against Days", fontsize="14")
plt.xlabel("Days", fontsize="12")
plt.ylabel("kW", fontsize="12")
plt.show()
```

Output



PI.py

```
# Construction Cost * Unemployment% / (Area * Duration)
# Check crop farm cost, regenerative

fac=['sports centre ','ski facility ','grazing farm ','regenerative farm ','agrivoltaic farm
','agritourist centre ']
county=['wayne','cayuga','seneca','onondaga','oswego']
con_cost=[32,20,0.69802,0.32,0.879546,0.094267]
dur=[2.5,3,1.15,1.15,1.5,1.5,1.5]
area=[0.5,1.5,0.809,0.809,0.809,0.00018]

# Unemployment
employed = [41300, 33700, 13900, 213800, 50100]
unemployed = [1800, 1500, 600, 8500, 2800]

labour_force = sum(employed) + sum(unemployed)
unemployed_per = sum(unemployed) / labour_force * 100
print( 'Old unemployment% (pre micron)= '+str(unemployed_per))

n=0
list_PI=[]
sorted_PI=[]
```

```python
for x in con_cost:
    PI = con_cost[n] * unemployed_per / (area[n] * dur[n])
    #print(f"{fac[n]} {PI}")
    list_PI.append(PI)
    sorted_PI.append(PI)
    n+=1

sorted_PI.sort()

minimum = sorted_PI[0]
_range = sorted_PI[-1] - sorted_PI[0]
#print(f'Range = {_range}')
#print(f'Minimum = {minimum}')

n=0
values = []
for x in sorted_PI:
    normalised = 1+ (list_PI[n] - minimum)*9 / _range
    values += [f"{fac[n]}:{normalised}"]
    n+=1
print(values)
# Assume 10% of jobs(direct and indirect) go to community
per = 0.1
jobs_direct = 9000 * per
jobs_indirect = 40000 * per
new_employed = jobs_direct + jobs_indirect + sum(employed)
new_unemployed_per = (1 - new_employed / labour_force) * 100
print('New unemployment% (post micron)= '+str(new_unemployed_per))

n=0
list_PI=[]
sorted_PI=[]

for x in con_cost:
    PI = con_cost[n] * new_unemployed_per / (area[n] * dur[n])
    list_PI.append(PI)
    sorted_PI.append(PI)
    n+=1

sorted_PI.sort()

minimum = sorted_PI[0]
_range = sorted_PI[-1] - sorted_PI[0]


n=0
new_values = []
for x in sorted_PI:
    normalised = 1+ ((list_PI[n] - minimum)*9/ _range )
    new_values += [f"{fac[n]}, {normalised}"]
    n+=1
print(new_values)
```

Output

```
Old unemployment% (pre micron)= 4.130434782608695
['sports centre :1.6516883606746702', 'ski facility :1.105805971757879', 'grazing farm
:1.010484387516608', 'regenerative farm :1.0', 'agrivoltaic farm :1.00982702901101', 'agritourist
centre :10.0']

New unemployment% (post micron)= 2.798913043478257
['sports centre , 1.6516883606746702', 'ski facility , 1.105805971757879', 'grazing farm ,
1.010484387516608', 'regenerative farm , 1.0', 'agrivoltaic farm , 1.00982702901101', 'agritourist
centre , 10.0']
```

SB.py

```python
import pandas as pd
import numpy as np

benefits = pd.read_csv('data/SB Data/SB(interactions).csv', delimiter =',')
salarys = pd.read_csv('data/SB Data/SB(salary).csv', delimiter =',')


for benefit in benefits.iterrows():
    social_interaction_benefits = (benefits['People affected'] * benefits['Magnitude'] * benefits['Duration'])/1000 #devided by 1000 to decrease the value down

benefits['Social interaction benefit score'] = social_interaction_benefits

#normalised salary to create a magnitude of salary ranging between 2 to 4 inclusive.
salary_magnitude = pd.read_csv('data/SB Data/SB(salary raw).csv', delimiter =',')
for value in salary_magnitude.iterrows():
    magnitude_salary = 2 + (((salary_magnitude['Salary']-np.nanmin(salary_magnitude['Salary']))*(4-2))/(np.nanmax(salary_magnitude['Salary'])-np.nanmin(salary_magnitude['Salary'])))

salarys['Magnitude'] = magnitude_salary


for salary in salarys.iterrows():
    salary_benefits = (salarys['People affected'] * (salarys['Magnitude']*salarys['Duration']))/1000 #devided by 1000 to decrease the value down

salarys['salary benefits'] = salary_benefits



#summation function for over all social benefits (Social interaction and Job salary)
overall_social_benefits = benefits['Social interaction benefit score'] + salarys['salary benefits']

final_table = pd.DataFrame({})
final_table['Facilities'] = benefits['Facilities']
final_table['Overall score'] = overall_social_benefits


#normalised total social benefits score ranging between 1 to 10 inclusive
for x in final_table.iterrows():
    normalised_socialbenefits = 1 + ((final_table['Overall score']-np.nanmin(final_table['Overall score']))*(9))/(np.nanmax(final_table['Overall score'])-np.nanmin(final_table['Overall score']))
    final_table['Normalised Score'] = normalised_socialbenefits

print(final_table)
```

Output

```
           Facilities  Overall score  Normalised Score
0       sport complex     741.520000         10.000000
1      skiing facility    159.906873          1.599944
2         grazing farm    118.367206          1.000000
3     regenrative farm    118.367206          1.000000
4      agrivoltic farm    118.367206          1.000000
5   agritourist centre    414.800000          5.281286
```

NPV.py

```python
import pandas as pd
import numpy as np

npvs = pd.read_csv('data/Economic Data/NPV.csv', delimiter =',')
expected_annual_return_rate = (npvs['profits']/(npvs['revenue']-npvs['profits']))
npvs['expected annual return rate'] = expected_annual_return_rate

for y in npvs.iterrows():
    npvs['future present value'] = npvs['revenue']-npvs['maintenance cost']

for npv in npvs.iterrows():
    present_value_for_year_1 = npvs['future present value']/(1 + npvs['expected annual return rate'])**1
    present_value_for_year_2 = npvs['future present value']/(1 + npvs['expected annual return rate'])**2
    present_value_for_year_3 = npvs['future present value']/(1 + npvs['expected annual return rate'])**3
    present_value_for_year_4 = npvs['future present value']/(1 + npvs['expected annual return rate'])**4
    present_value_for_year_5 = npvs['future present value']/(1 + npvs['expected annual return rate'])**5

    npvs['Total present value'] = present_value_for_year_1 + present_value_for_year_2 + present_value_for_year_3 + present_value_for_year_4 + present_value_for_year_5

#grazing farm often lost first year benefits
npvs.at[5,'Total present value'] = ((npvs.iloc[5,7])*(4/5))

net_present_value = npvs['Total present value'] - npvs['initial invested value']
npvs['net present value'] = net_present_value

#skiing facilities can only operate 1 quarter of the year
npvs.at[0,'net present value'] = ((npvs.iloc[0,8])/4)


for x in npvs.iterrows():
    normalised_net_present_value = 1 + (((npvs['net present value']-np.nanmin(npvs['net present value']))*(9))/(np.nanmax(npvs['net present value'])-np.nanmin(npvs['net present value'])))
    npvs['Normalised Score'] = normalised_net_present_value
print(npvs)
```

Output

```
                    Facilities  profits  ...  net present value  Normalised Score
0  cross country skiing facility  2000000  ...      338736.000000          7.354295
1          outdoor sport complex   305208  ...      475941.923835         10.000000
2              regenerative farm    22781  ...      248053.827693          5.605695
3               agrivoltaic farm    35491  ...      243660.922096          5.520988
4                   grazing farm    40000  ...      246654.063111          5.578704
5             agritourist centre     8162  ...        9203.038498          1.000000
```

main.py

```python
from PI import values as PIdata
from NPV import npvs as NPVdata
from SB import final_table as SBdata
import numpy as np
import pandas as pd

final = pd.DataFrame()
PIframe = pd.DataFrame()
PIdata = np.array(sorted(PIdata))
sortedNPV = NPVdata.sort_values(by='Facilities', axis=0).reset_index()
sortedSB = SBdata.sort_values(by='Facilities', axis=0).reset_index()

final['Facilities'] = sortedNPV['Facilities']
PIframe['Facilities'] = sortedNPV['Facilities']


for i, index in enumerate(PIdata):
    PIframe.loc[i, 'Normalised Score'] = float(index.split(':')[1])

SBweight = 0.3
PIweight = 0.2
NPVweight = 0.5

print(PIframe)

final["Overall Score"] = SBweight * SBdata['Normalised Score'] + NPVweight * NPVdata["Normalised Score"]  + PIweight * PIframe["Normalised Score"]

print("\n",final)
```

Output

```
                     Facilities  Overall Score
0             agritourist centre       8.677148
1               agrivoltaic farm       5.681949
2  cross country skiing facility       3.304945
3                   grazing farm       3.260494
4           outdoor sport complex       3.310513
5               regenerative farm       2.414723
```

FLP.py

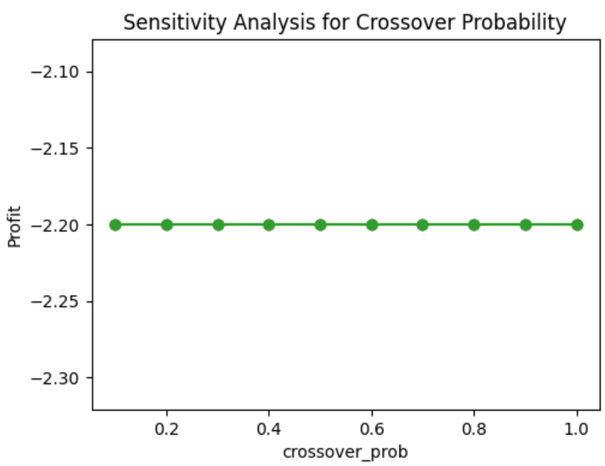
```
import pandas as pd
import numpy as np
from pymoo.algorithms.moo.nsga2 import NSGA2
from pymoo.config import Config
from pymoo.core.problem import Problem
from pymoo.optimize import minimize
from pymoo.termination import get_termination
import json
import matplotlib.pyplot as plt
Config.warnings['not_compiled'] = False

def locationnum(locations):
    if "agritourist centre" in locations or "cross country skiing facility" in locations:   # these take up 2 locations
        return list(range(1,4))
    else:
        return list(range(1,4))

                                                    #1          #2          #3
datadict = {
    'cross country skiing facility': {'NPV':  np.array([7.354295,7.354295,7.354295*1.2]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])},
    'outdoor sport complex': {'NPV': np.array([10.000000,10.000000,10.000000]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])},
    'regenerative farm': {'NPV': np.array([5.605695*1.2,5.605695*1.2,5.605695*0.8]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])},
    'agrivoltaic farm': {'NPV': np.array([5.520988*1.2,5.520988*1.2,5.520988*0.8]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])},
    'grazing farm': {'NPV': np.array([5.578704,5.578704,5.578704]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])},
    'agritourist centre': {'NPV': np.array([1.000000,1.000000*1.2,1.000000*0.8]), 'SB_scores': np.array([84.1/10,43.8/10,75/10])}
}

# data = pd.DataFrame.from_dict(data=datadict, orient='index')
locations = input("Input 3 facilities(separated by commas, no spaces. If F = skiing or agritourist then enter the same F twice) \n Enter Here: ")
```

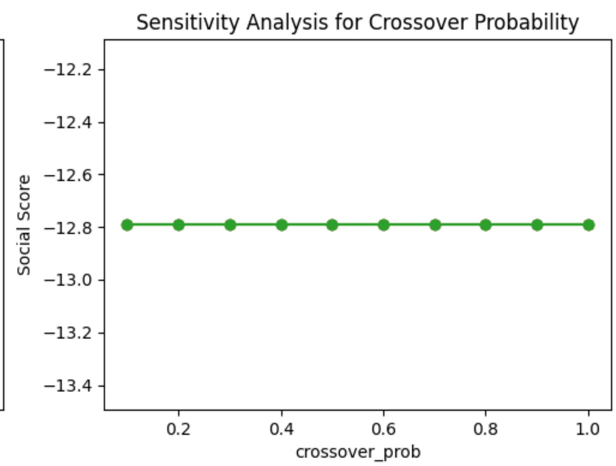
```
location_ids = locationnum(locations)
class FLP(Problem):

    def __init__(self, datadict, locations, location_ids):
        #self.data = data
        self.locations = locations
        self.location_ids = location_ids
        self.datadict = datadict

        super().__init__(
            n_var=len(location_ids),
            n_obj=2,
            n_constr=0,
            xl=0,
            xu=1
        )

    def _evaluate(self, x, out, *args, **kwargs):
        selected_locs = np.round(x).astype(int)
        unique_locs = np.unique(selected_locs)
        if 0 in unique_locs:
            unique_locs = unique_locs[1:]

    # Iterate over different locations and calculate their objective function values
        NPV_per_location = []
        SB_scores_per_location = []

        for i, loc in enumerate(self.locations.split(',')):
            loc_idx = self.location_ids[i] - 1

            loc_NPV = datadict[loc]['NPV']
            loc_SB_scores = datadict[loc]['SB_scores']
            print(loc_NPV)


            mask = (selected_locs == self.location_ids[i])
            profit_value = -np.sum(loc_NPV[mask[loc_idx]])
            SB_score_value = -np.sum(loc_SB_scores[mask[loc_idx]])


            NPV_per_location.append(profit_value)
            SB_scores_per_location.append(SB_score_value)

        out["F"] = np.column_stack([NPV_per_location, SB_scores_per_location])




problem = FLP(datadict, locations, location_ids)
algorithm = NSGA2(pop_size=len(location_ids), crossover_prob=0.8, mutation_prob=1/3, tournament_size=len(location_ids))
res = minimize(problem, algorithm, termination=('n_gen', 100), seed=1)


for i, loc in enumerate(locations.split(',')):
    loc_idx = location_ids[i] - 1
    selected_locs = res.X[loc_idx]

    # Print the name of the location
    print(f"\nInput {i+1} Facility: {loc}\n")

    # Iterate over different locations and print the selected locations
    for j, sel_loc in enumerate(selected_locs):
        if sel_loc > 0:
            print(f"Selected Location {j+1}: {sel_loc}")
```

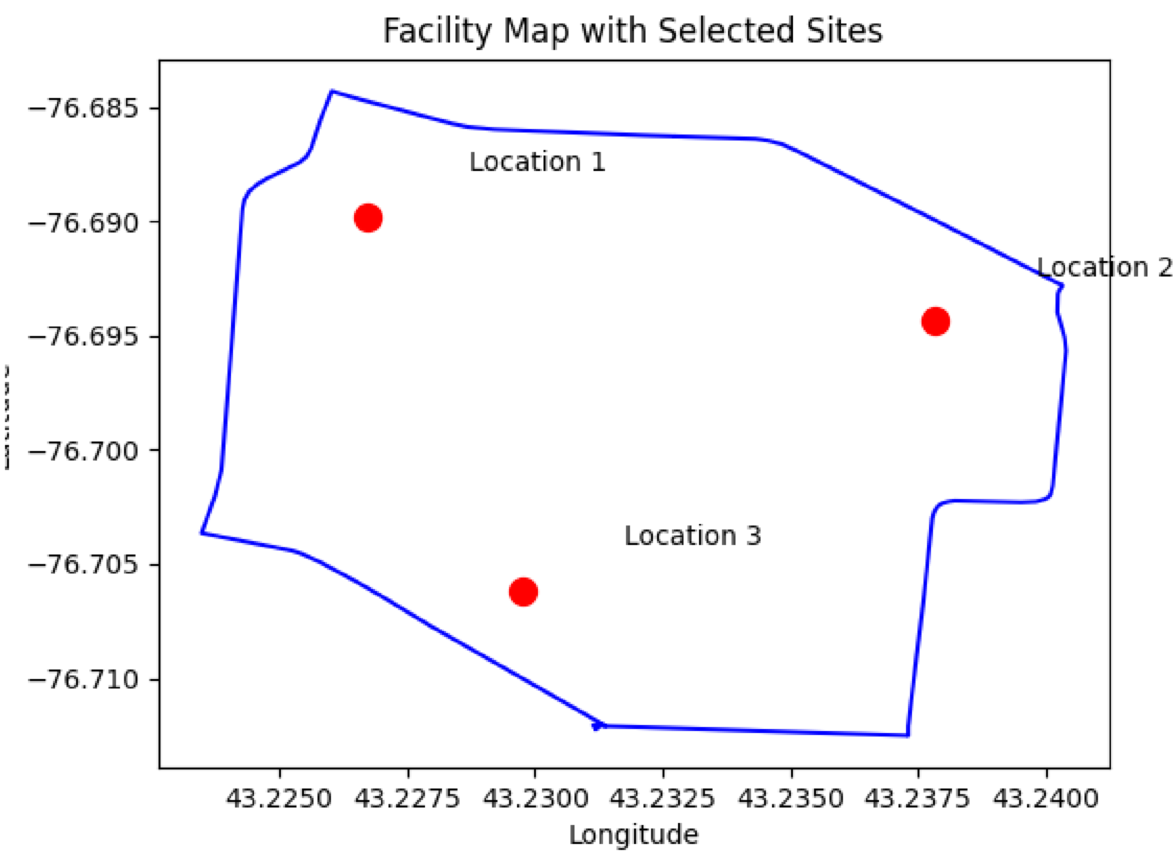
```
### TO SEE LOCATION RESULTS, UNCOMMENT THE QUOTATIONS BELOW

###'''
from pymoo.indicators.hv import HV

ref_point = np.array([1.2, 1.2])

ind = HV(ref_point=ref_point)


from pymoo.visualization.scatter import Scatter

problem = FLP(datadict, locations, location_ids)

# Define the parameters to be varied
n_variations = 10
param_name = 'crossover_prob'
param_values = np.linspace(0.1, 1.0, n_variations)

# Run the optimization with varying parameter values
results = []
for value in param_values:
    algorithm = NSGA2(pop_size=len(location_ids), crossover_prob=value, mutation_prob=1/3, tournament_size=len(location_ids))
    res = minimize(problem, algorithm, termination=('n_gen', 100), seed=1)
    results.append(res)

# Extract the objective values
NPV = []
SB_scores = []
for res in results:
    NPV.append(res.F[:,0])
    SB_scores.append(res.F[:,1])

# Plot the results
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(12, 4))

ax1.set_title("Sensitivity Analysis for Crossover Probability")
ax1.set_xlabel(param_name)
ax1.set_ylabel("Profit")
ax1.plot(param_values, NPV, 'o-')

ax2.set_title("Sensitivity Analysis for Crossover Probability")
ax2.set_xlabel(param_name)
ax2.set_ylabel("Social Score")
ax2.plot(param_values, SB_scores, 'o-')

plt.show()

with open('data/map.json') as f:
    data = json.load(f)

fig, ax = plt.subplots()
ax.set_title('Facility Map with Selected Sites')
ax.set_xlabel('Longitude')
ax.set_ylabel('Latitude')
coords = data['features'][0]['geometry']['coordinates'][0]
lats, longs = zip(*coords)
ax.plot(longs, lats, color='blue')

facilities = [(43.226727, -76.689821, 'Location 1'), (43.237822, -76.694381, 'Location 2'), (43.22976624916421, -76.7061705481701, 'Location 3')]

for facility in facilities:
    ax.plot(facility[0], facility[1], marker='o', markersize=10, color="red")
    ax.text(facility[0] + 0.002, facility[1] + 0.002, facility[2])

plt.show()


print("HV", ind(res.F))
### '''
```

Output

```
Input 1 Facility: agritourist centre

Selected Location 1: 0.5398733354561448
Selected Location 2: 0.6636639327543548
Selected Location 3: 0.24962736064771932

Input 2 Facility: agrivoltaic farm

Selected Location 1: 0.6012222397117142
Selected Location 2: 0.6636639327543548
Selected Location 3: 0.050640077654080795
```








```
HV 47.566
```

Appendix B

/data/Crop Data/Food_Production.csv

Food product	Eutrophying emissions per 1000kcal (gPO_4eq per 1000kcal)	Greenhouse gas emissions per 1000kcal ($kgCO_2eq$ per 1000kcal)	Land use per 1000kcal (m^2 per 1000kcal)	Land use per kilogram (m^2 per kilogram)	Scarcity-weighted water use per kilogram (litres per kilogram)
Wheat & Rye (Bread)					
Maize (Meal)					

Barley (Beer)					
Oatmeal	4.281357225	0.945482272	2.897445673	7.6	18786.2
Rice	9.51437873	1.207270754	0.7596310359999999	2.8	49576.3
Potatoes	4.7540983610000005	0.628415301	1.202185792	0.88	2754.2
Cassava	0.708418891	1.35523614	1.8583162219999998	1.81	0.0
Cane Sugar	4.820512821	0.911680912	0.581196581	2.04	16438.6
Beet Sugar	1.5413105409999999	0.515669516	0.5213675210000001	1.83	9493.3
Other Pulses	5.008797653999999	0.524926686	4.565982405	15.57	22477.4
Peas	2.173410405	0.28323699399999996	2.156069364	7.46	27948.2
Nuts	3.113821138	0.069918699	2.107317073	12.96	229889.8
Groundnuts	2.437931034	0.556896552	1.570689655	9.11	61797.9
Soymilk				0.66	955.6
Tofu					
Soybean Oil				10.52	14888.2
Palm Oil	1.207013575	0.828054299	0.273755656	2.42	36.2
Sunflower Oil	5.730769231	0.407239819	1.9977375569999998	17.66	36369.4
Rapeseed Oil	2.17081448	0.426470588	1.2024886879999999	10.63	10593.7
Olive Oil	4.214932127	0.6131221720000001	2.976244344	26.31	177480.2
Tomatoes	39.52631579	11.0	4.210526316	0.8	5335.7
Onions & Leeks	8.756756757	1.351351351	1.054054054	0.39	932.0
Root Vegetables	4.351351351	1.162162162	0.8918918920000001	0.33	929.2
Brassicas	29.47058824	3.0	3.235294118	0.55	8455.1
Other Vegetables				0.38	4911.4
Citrus Fruit	7.0	1.21875	2.6875	0.86	4662.7
Bananas	5.483333332999999	1.4333333330000002	3.2166666669999997	1.93	661.9
Apples	3.020833333	0.895833333	1.3125	0.63	12948.6
Berries & Grapes	10.73684211	2.6842105259999998	4.228070175	2.41	21162.1
Wine				1.78	1149.3
Other Fruit				0.89	9533.1
Coffee	197.3571429	50.94642857	38.60714286	21.62	337.0
Dark Chocolate	16.84332689	9.023210832	13.3384913	68.96	2879.2
Beef (beef herd)	110.4065934	36.43956044	119.4908425	326.21	34732.5
Beef (dairy herd)	133.8058608	12.1978022	15.83882784	43.24	119805.2
Lamb & Mutton	30.64037855	12.52996845	116.659306	369.81	141925.0
Pig Meat	31.958159000000002	5.150627615	7.263598326	17.36	66867.4

Poultry Meat	26.32432432	5.335135135	6.605405405	12.22	14177.9
Milk	17.75	5.25	14.91666667	8.95	19786.3
Cheese	25.41860465	6.170542636	22.68475452	87.79	180850.6
Eggs	15.11111111	3.2430555560000003	4.354166667	6.27	17982.7
Fish (farmed)	131.35195530000001	7.61452514	4.6983240219999995	8.41	41572.2
Shrimps (farmed)					

/data/Crop Data/foodreturns.csv

Product	Gross income per acre ($)
Beef	200
Apples	2324
Tomatoes	2000
Potatoes	2075

data/Demographics & Energy/population.csv

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019												
"Victory town Cayuga County New York"		"1	656"	"1	652"	"1	644"	"1	639"	"1	625"	"1	609"	"1	598"	"1	590"	"1	579"	"1	565"
"Port Byron village New York"	"1	254"	"1	249"	"1	240"	"1	235"	"1	225"	"1	214"	"1	204"	"1	200"	"1	197"	"1	189"	
"Auburn city Cayuga County New York"		"27	666"	"27	549"	"27	354"	"27	177"	"27	060"	"27	004"	"26	761"	"26	634"	"26	486"	"26	173"
"Cato town Cayuga County New York"		"2	534"	"2	528"	"2	522"	"2	515"	"2	499"	"2	479"	"2	461"	"2	453"	"2	442"	"2	425"

"Lysander town Onondaga County New York"	"2 1	82 2"	"2 2	02 4"	"2 2	22 7"	"2 2	22 2"	"2 2	31 5"	"2 2	62 0"	"2 2	68 5"	"2 2	83 4"	"2 2	90 1"	"2 2	89 6"
"Oswego city Oswego County New York"	"1 8	14 0"	"1 8	07 6"	"1 8	11 1"	"1 7	98 5"	"1 7	85 9"	"1 7	74 4"	"1 7	57 2"	"1 7	45 6"	"1 7	33 3"	"1 7	23 6"
"Sodus town Wayne County New York"	"8	37 3"	"8	32 6"	"8	31 8"	"8	24 6"	"8	22 3"	"8	15 8"	"8	10 2"	"8	06 9"	"8	04 7"	"8	02 7"

/data/Demographics & Energy/solarenergy.csv

https://www.commonwealthsec.moe.edu.sg/https://www.commonwealthsec.moe.edu.sg/ (Data too long to insert)

/data/Demographics & Energy/temperature.csv

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1990	33.2	29	37.5	49.3	54.5	67.3	71.8	70.3	61.2	52.8	42.2	33.5	50.2
1991	24.3	29.8	37.7	51	62.7	68.4	72.3	71.8	60.5	53.1	40	30.7	50.2
1992	24.7	26.4	29.3	44.4	57.5	64	67.3	67.5	61.3	46.6	39.7	31	46.6
1993	27.5	17	30	46.9	58	65.1	72.4	70.6	60	48.2	38.6	26.9	46.8
1994	12.6	19.2	30.8	47.9	54.1	68	72.9	67.5	60.9	50.6	44	31.9	46.7
1995	30.5	20.7	37.4	42.4	56.9	69.5	73.5	71.9	59.1	54.7	35.3	24.2	48
1996	22.5	24.7	29.8	43.2	54.9	68.2	69.4	70.3	63.1	50.6	34.7	34.8	47.2
1997	23.8	30.3	33.5	44.2	52.2	67.9	69.8	68.4	60.1	49	37.2	30.4	47.2
1998	29.6	31.2	37.8	48.1	62.9	66.3	70.1	71.1	64	51.8	41.7	35.4	50.8
1999	22.5	29.6	31.5	46.5	60.7	69.8	75	68.9	64.8	49.5	44.3	30.9	49.5
2000	21.3	28.8	40	44.3	59.1	65.6	67	68.1	60.7	50.9	38.4	21.6	47.2
2001	25.6	27.6	29.9	47.8	59.3	67.2	69.4	73.6	62.3	53.3	47.3	36.8	50
2002	32.9	32.3	36.3	48.5	54	68	73.7	73	66.9	50.4	40.6	28.7	50.4
2003	18.8	21.6	34.2	43.8	56	64.6	71.2	71.5	63.2	48.6	42.2	30	47.1
2004	14.7	23.5	37.5	46.1	60.3	63.7	69.5	68.6	65	51.4	41	29.1	47.5
2005	21	25.7	30.7	48.3	54.2	72.7	74.7	73.7	65.4	52.1	44	26.2	49.1
2006	33.4	27.2	34	47.8	58.2	67.2	74.1	69.2	60.7	49.2	44.7	37.4	50.3
2007	27.2	18.5	31.5	43.7	58.5	68.3	69.8	70.8	65.3	58	37.9	27.9	48.1
2008	29.5	25.7	31.6	51.6	53.7	69.7	71.3	66.9	62.7	48.3	38.2	28.9	48.2
2009	18.2	26.3	35.3	48.2	57.5	64.7	68	70.9	61.3	49	43.5	28.1	47.6

2010	23.2	25.9	40.5	51.8	61.1	67.5	74.5	71.4	63.1	51.3	40.8	25.5	49.7
2011	21	23.8	33.3	49.2	62.8	68.9	75.8	71.9	66	52.6	46.8	35.9	50.7
2012	31.1	32.3	46.5	45.9	64.3	68.8	76.2	73	63.6	54.2	39.3	35.3	52.5
2013	27.7	25.3	33.6	46.1	60.4	66.8	74.5	70	61.3	53.8	37.7	27.9	48.8
2014	19.9	20.9	25.7	46	60.4	68.8	71.4	69.2	63.8	54.9	39.7	32.1	47.7
2015	17.3	9	27	46.4	64.1	66	71	70.5	67.9	49.9	46	41.1	48
2016	25.9	27.6	39.7	42.6	58.2	66.3	73.3	74.1	64.8	51.6	41.8	29.6	49.6
2017	29.1	33.3	30.1	50.9	55.7	65.9	70.3	68.2	64.5	57	38	24.1	48.9
2018	21.5	32.2	30.8	39.5	62.8	65.6	73.7	72.5	65.6	49.9	34.5	30.7	48.3
2019	21.4	26.6	32.4	48.2	57	66	74.8	69.7	63.9	53.5	36	30.5	48.3
2020	31	28.5	40.3	44.4	56.8	69.3	77.1	73	63.8	51.9	45.6	33.8	51.3
2021	27.2	25.1	38.6	49.2	59	72.6	72.4	75.5	66	59	41.1	38	52
2022	19.5	27.8	37	45.8	61.5	66	74.1	74.3	64	52.5	45.2	32.1	50

/data/Economic Data/NPV.csv

, Facilities,profits,revenue,maintenance cost,initial invested value
,cross country skiing facility,2000000,10000000,200000,25000000
,outdoor sport complex,305208,1129386,160000,1600000
,regenerative farm,22781,354000,124000,698082
,agrivoltaic farm,35491,432000,143600,879546
,grazing farm,40000,225000,28720,320000
,agritourist centre,8162,50230,7550,94267

data/SB Data/SB(interactions).csv

Facilities	People affected	Magnitude	Duration
sport complex	109	2	2600
skiing facility	109	2	516
grazing farm	55	1	1300
regenrative farm	55	1	1300
agrivoltic farm	55	1	1300
agritourist centre	109	2	1300

data/SB Data/SB(salary raw).csv

facility	Salary
Sport complex	59840
skiing facility	62572
grazing farm	61875
regenrative farm	61875
agrivoltaic farm	61875
agritourist centre	88900

data/SB Data/SB(salary).csv

Facilities	People affected	Duration
sport complex	42	2080
skiing facility	42	516
grazing farm	10	2190
regenrative farm	10	2190
agrivoltic farm	10	2190
agritourist centre	15	2190

data/map.json

{"features":[{"geometry":{"coordinates":[[[-76.71220779418947,43.23119629494612],[-76.71201213009932,43.231329094679204],[-76.71209,43.23139],[-76.71209,43.23139],[-76.71250416529043,43.23731052677468],[-76.71250414945347,43.23731],[-76.71211,43.23731],[-76.70654,43.23761],[-76.70654,43.23761],[-76.703,43.23778],[-76.70269,43.23782],[-76.70247,43.23789],[-76.70234,43.23798],[-76.70227,43.23809],[-76.70223,43.23822],[-76.7023,43.23952],[-76.70227,43.23981],[-76.70217,43.23998],[-76.70208,43.24005],[-76.70194,43.2401],[-76.70157,43.24014],[-76.69566,43.2404],[-76.69507,43.24037],[-76.69398,43.24023],[-76.6932,43.24024],[-76.69304,43.24026],[-76.69281,43.24033],[-76.69281004303872,43.240329992678795],[-76.68979,43.23769],[-76.68692,43.23513],[-76.68662,43.23483],[-76.68647,43.23457],[-76.68639,43.23432],[-76.68628193763442,43.232756697778015],[-76.68628193763442,43.23275670555948],[-76.68624,43.23215],[-76.68598,43.2292],[-76.68598,43.2292],[-76.68587,43.22869],[-76.68572,43.22837],[-76.68457,43.22642],[-76.68457,43.22642],[-76.68430766070973,43.22602401646744],[-76.68430766070973,43.22602401646744],[-76.68457,43.22598],[-76.68457,43.22598],[-76.68552,43.22581],[-76.68678,43.22563],[-76.68718,43.22553],[-76.68742,43.2254],[-76.68811,43.22478],[-76.68835,43.22459],[-76.68869,43.22441],[-76.68906,43.22432],[-76.68944,43.22428],[-76.70088,43.22387],[-76.70202,43.22374],[-76.70306054625482,43.22357299880535],[-76.70306054625482,43.22357299880535],[-76.70364,43.22348],[-76.70364686121182,43.2234783932819],[-76.70382470356603,43.22388891924492],[-76.70382470356603,43.22388891924492],[-76.70441,43.22524],[-76.70455,43.22544],[-76.70491,43.22579],[-76.70577,43.22651],[-76.70654,43.2271],[-76.70654,43.2271],[-76.70771,43.22796],[-76.70929,43.2292],[-76.70929,43.2292],[-76.71151602123568,43.23094106660934],[-76.7115160212357,43.23094107027068],[-76.71184376837076,43.23119741168998],[-76.71184376837076,43.23119741168998],[-76.71209,43.23139],[-76.71209,43.23139],[-76.71205,43.23126],[-76.71204151716348,43.23114350237854],[-

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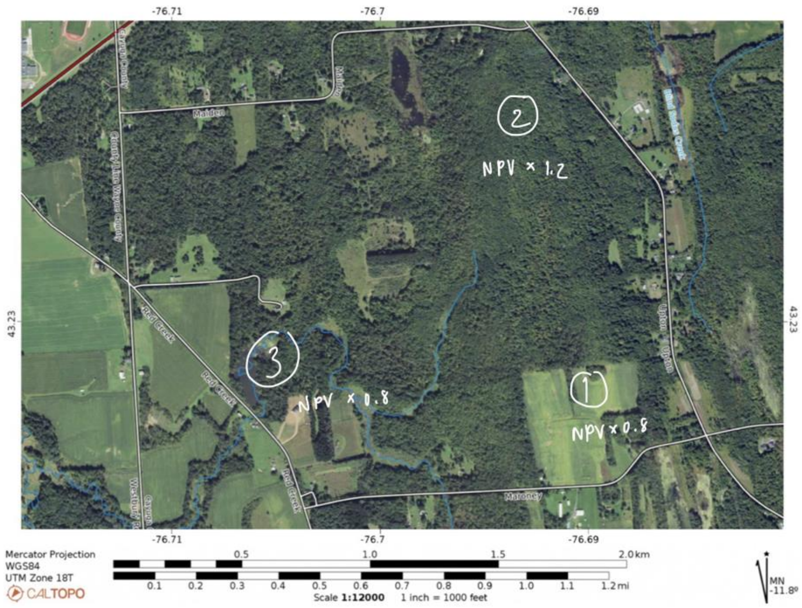
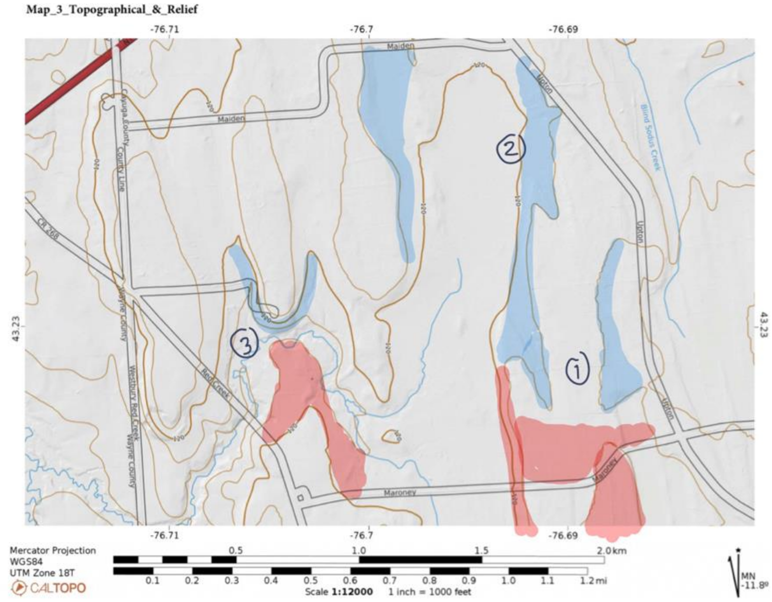
FLP condition value

Map_1_Satellite



Map_3_Topographical_&_Relief



Map 4 Current Cell Coverage