SITE SUITABILITY FOR DEVELOPING NEW COLD CHAIN USING MULTI-CRITERIA DECISION ANALYSIS AND GEOSPATIAL TECHNIQUES

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ABSTRACT:

Growth and performance of various sectors of a country largely depends on the infrastructure developed by the country. It is true about the agricultural sector also. Along with the numbers, the location of these infrastructure play a vital role in reducing cost to the farmers while utilizing the existing resources like land, water, electricity and road network to their optimum level. India is the second largest producer of fruits, vegetable and tea. Against the total production of more than 500 MMT of horticultural & non-horticultural produces, the total cold storage capacity is estimated at approximately 31 MMT, which is not even 10% of the total production. In view of this, a site suitability study was conducted to develop an optimum plan to locate cold storages in the state of Uttar Pradesh, a leading potato growing state. Factors considered for evolving the plan includes the site of production, i.e. region where potato is grown, road network, existing cold storage, electricity and land use. When there are various factors behind any decision-making process, it becomes a complex process. It becomes difficult to decide which factor is to be given more importance and how other factors can be compounded with each other to arrive at a decision. Analytical Hierarchy process (AHP), helps us in determining the relative importance of various factors to arrive at a decision. In view of infrastructure planning, an illustrative map indicating spatial features is vital. As is widely established, remote sensing and GIS helps to obtain such a spatial map. Remote sensing and GIS was used to generate maps of the factors involved. AHP was used to develop weights of the factors in relation to each other to generate a map showing site suitability of places for developing cold storage facilities.

1. INTRODUCTION

India is the largest producer of milk and the second largest producer of fruits, vegetables and tea. Annual wastage of fruits and vegetables is estimated to range from 5.8% to 18% having value of 205 crores USD. Against the total production of more than 500 MMT of horticultural & non-horticultural produces, the total cold storage capacity is estimated approximately 31 MMT, which is not even 10% of the total production. A study conducted by the National Spot Exchange Ltd. (NSEL) in December, 2010 estimated a cold storage requirement of 61.13 million tonnes in the country. Ministry of food processing industry's scheme of cold chain has been up-scaled for taking another 75 cold chain projects (MOFPI, 2014).

Potato is the third most important food crop in the world after rice and wheat. Popularity of potato is increasing in densely populated countries, including developing countries because of its adaptability in different cropping systems and agro-climatic conditions with high productivity. It is cultivated in around 1.25% of total cultivable area in India, with Uttar Pradesh (UP) producing about 37% of total production of the country. The area under the crop is gradually increasing with a concurrent increase in the productivity. The consumption of table potato as well as the requirement of seed potato is more or less stable in the state and other major states. A small quantity is utilized for processing. A major portion of about 10-15% of the production is wasted due to post harvest losses. Analysis of production, consumption and market prices during past years indicates a trend of potato prices falling every third or fourth year in the situation whenever the production increases by 7-8%. It is, therefore required to manage 17-23% of potato production through appropriate storage facilities, so that the price fluctuation can be controlled and losses to the farmers can be minimized. Developing cold storages is the only solution to absorb the additional increase in the production and enable farmers to avoid distress sale.

As it is important to increase the number of cold storages, so it is important to understand the location of them that would cater to highest utility to the farmers in the given set of other available resources. Site selection of cold storages is one of the key components that determine its usefulness. Site selection of a building involves the evaluation of various aspects with different degrees of importance or influence. To ensure that the critical aspects of site selection are not overlooked, a methodology has to be evolved (Kumar and Bansal, 2016). The procedure of site suitability analysis requires the appropriate selection of land for the particular objective by considering various parameters, like elevation, slope, aspect, soils, hydrology, flora and fauna habitat, land use, manmade facilities such as transportation systems, existing built up areas, etc. These different types of information constitute the "criteria". Combining these criteria in an optimum way such that their combination is considered in appropriate weightage or priority, constitute multi criteria analysis.

Analytic hierarchy process (AHP) is such a process used for multi-criterion decision making. It was firstly developed by Saaty (1980). It determines the weight or importance for

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different land use based on pairwise comparisons of various parameters according to their relative significance (Miller et al. 1998).

The process of multicriteria analysis involves combination of various criteria and their inter-relationship. This needs to be tested in each minutest point or unit of the whole study area. Geospatial data of any criterion consists of a contiguous map containing information or status of that criterion. If all the criteria maps are arranged in a layer, it could be possible to determine the set of condition that exists in any given point or pixel of the image. Thus, in order to have an output, showing the status of combination of all the input criteria at all points of the study area, geospatial data of each criteria are taken into consideration. GIS Software makes it possible to construct maps to be used as inputs, analyze the spatial information, edit data and maps to bring them in the format that can be incorporated in the AHP and also present the results of all these operations in map format.

Keeping in view the urgency of developing cold storages in the northern part of the country, the present study discusses the site suitability of these cold storages with the given set of existing conditions or 'criteria'.

2. STUDY AREA AND DATA USED

2.1 Study Area

The study was carried out for the state of Uttar Pradesh. The state has the maximum number of cold storages, which are used more for the potato crop in northern India. Uttar Pradesh is located between 77.085^0 E, 30.412^0 N and 84.63^0 E, 23.87^0 N. State is divided and also divided into 9 agro-climatic zones, namely, Bhabhar & Tarai, Western Plain, Central-Western Plain, South-Western Plain, Central Plain, Bundelkhand, North-Eastern Plain, Eastern Plain, and Vindhyan region. Uttar Pradesh lies in the warm temperate zone. The annual rainfall in the eastern part of the U.P. varies between 100 and 120 cm. South-west monsoon lasts in U.P. from June to September, covering about 83% of the total rainfall while winter rains cover the remaining 17%. The location map of the study area is given in Figure1.

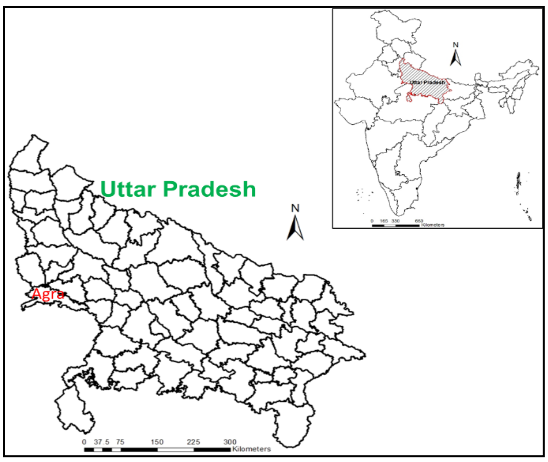

Figure 1. Study area for cold storage development in Uttar Pradesh

2.2 Geospatial Data used

Data used were divided into two categories of criteria – factors and constraints. A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. A constraint serves to limit the alternatives under consideration or the area that is not preferred in any way or considered unsuitable. Constraints do not participate in the weight assignment process. Geospatial data used for the study are given in Table 1.

	Layers	**Geospatial data type**
1.	Existing Cold storage	Point Vector
2.	Potato crop map	Raster
3.	Transport	Line Vector
4.	Agriculture markets	Point Vector
5.	Land Use (non-agriculture)	Raster
6.	Electrification	Raster
7.	Ground water	Raster
8.	Elevation	Raster
9.	Vulnerability to earthquakes	Raster
10.	Rivers and wetland	Polygon vector
11.	Sandy soil	Raster
12.	Drainage	Raster
13.	Built up	Polygon vector
14.	Areas within 25m of road/rail	Polygon vector
15.	Slope >30 degree	Raster
16.	25m areas around farm lands	Polygon vector

Table 1. Factors and constraints used for the study

3. METHODOLOGY

The methodology for the given study is divided into 4 major steps as shown in figure 1. For the present study, 11 factors were considered that participated in the decision-making process. Area covered by 4 constraints was masked out from the output map so that these areas can be avoided for building cold storages.

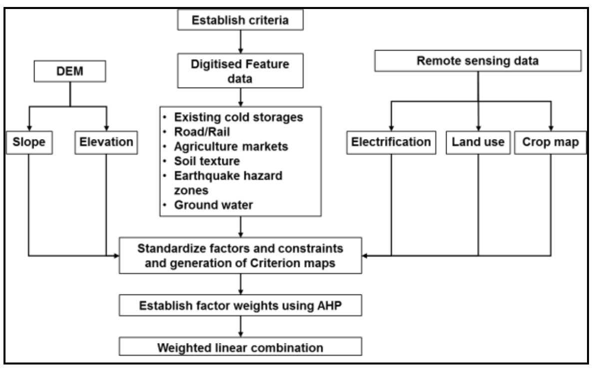

Figure 2. Methodology followed for developing suitability study of cold storages

3.1 **Identification of criteria:** Identification of parameters for site selection for constructing cold storage structures was done based on various literature. In one of these literatures, six aspects were identified that are generally considered in site selection, namely, topography, existing facilities/utilities, sub-soil dispersion system, roads/paths, open space, and overhead power lines (NBC, 2005). Few parameters were also considered from other literatures, such as, position of

sun/orientation, settlement, storm-water drains, soil erosion, vegetation, landslides, floods, earth-quake patterns, and climate, that may be considered in addition to the above mentioned six aspects. In the present study, a total of 16 criteria including 9 factors and 7 constraints were selected based on the literature and other requirements specific to the current objectives. Parameters such as sub-soil dispersion system and open spaces were not considered, given the larger scale of the study area. The selected criteria are specified in table 1.
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The set of factors used to analyze the suitability of the region for cold storages, has to consider 2 basic parameters – farmer’s aspects and construction aspects. That is, the site selection of the cold storages should be such that they are beneficial for the farmers as well as the sites should have all the desirable characteristics that supports construction and daily operations of a cold storage. For farmers, it is desirable that the new cold storages should be established in places such that –

- The new cold storages cater to those areas where there are lesser or no existing cold storages. In other words, the areas farther from the existing cold storages is preferable for new structures.
- The new cold storages should be near to the potato production areas so that transportation costs to the farmers is minimized
- In order to reduce cost for transportation, the nearer the cold storages to the road/rail network, lesser will be the cost incurred in transportation
- The new cold storages should be near to the mandis so that lesser transportation cost should be incurred for transporting the crop from cold storages to mandis/markets

For ensuring good sites for construction and daily operation of the cold storages they should be located such that –

- They avoid farm or forest lands and are preferably situated on wastelands
- Electricity and Ground water is easily available
- The elevation of the land is as less as possible
- Slope of the land should be less than 20^0
- Earthquake risk is minimum
- The soil should neither be sandy nor water logged
- The site selected should avoid existing built up area, rivers or other water bodies
- Area in very close proximity to existing transport system or farm lands should not be selected for new construction to avoid any adverse effect to transport system and farm lands.

3.2 **Standardization of factors and constraints:** For the multiple geospatial layers, to be able to interact with each other, they need to be on the same scale. Thus each of the factor data layers were brought to the same scale. Then, the raster layers were converted to polygons data layers. Now, the layers were there were majorly of two types – point and line vector layers, like location of cold storages and road and rail network. And another type of data consisted of polygons, like land use classes. Each layer was processed using ArcGIS to get 10 zones of preference, with zone 10 as most suitable and 1 as least suitable. For point or line data layers, like road, mandi, cold storages, etc., contours were made resembling various distances from the said structure and these contours were assigned ranks based on their desirability. The distances of contours depend on the scale of the study. Town level study will have smaller intervals, while regional level study will have larger intervals between contours. The polygons in the polygon data layers were ranked based on various parameters, like land use or crop production.

Then all data layers along with their classes or contours were converted to raster data layers. Each contours were assigned values ranging from 10 to 1 (10 being the most desired contour). The detailed standardization of all the factors are as given in table 2.

The rationale behind choosing the weightages and ranking of various factors, with 1 being assigned to the factor with lowest importance and vice versa are discussed as below -

3.2.1 **Existing cold storages:** The existing cold storages are already catering to an area. Thus new cold storages need to be planned such that they should be able to cater to the remaining areas. Thus the areas/contour farthest from the existing cold storage are given more importance and a value of 10. While the nearest contour got a value of 1.

3.2.2 **Farm site:** Farm site denotes the areas where potato crop is grown within the study area. It is desirable to have cold storages as near as possible to these areas. Thus the zones were ranked accordingly – contours nearest to the farm sites, i.e. at 1 km (ref. Table 2) was assigned maximum value (10) while farthest contours (280 km) was assigned the least weightage, 1. At the same time, a buffer zone of 25 m was used as constraint such that the area within 25 m around the farm sites should not be considered for the analysis at all. This was done to avoid encroachment of agricultural lands and to avoid any kind of other adverse effects of cold storages on the farm lands.

3.2.3 **Transportation:** For transportation, road and rail networks were considered. Good connectivity ensures easy and faster movement of produce to and from the cold storages. Thus higher values were given to proximity to transport system. Highest weightage is given to the availability of transportation network (road and rail) to be able to access the cold storages.

3.2.4 **Mandi/ market for agricultural produce:** Cost of transportation is less when the market is nearby. Thus, higher values were given for contours close to agriculture produce markets.

3.2.5 **Land use:** Land use that were given preference for building of cold storage are as given in table 2. Wastelands, Scrubland were given preference which are otherwise lying vacant. Agricultural land including fallow, and orchards were given the least weightage because the cold storages are not desirable in those areas. Similarly, forest areas had also lesser weightage.

3.2.6 **Electricity:** Electricity is one of the primary things required for building and operation of cold storages. Thus it was given a higher weightage when compared to other factors.

3.2.7 **Ground water:** Water is required for operation of cold storage structures. Thus nearness to water source enhances suitability of the area for establishment of cold storage structures.

3.2.8 **Slope:** Slope indicates the steepness, incline, or grade. 0^0-20^0 slope is most desirable for buildings. NBC (2005) suggests that no construction should be ordinarily undertaken in areas with slopes above 30^0. Most of the study area has a slope within 0^0 to 20^0. Thus, slope was not considered as a factor for this particular study. Slope more than 30^0 was considered as constraint factor.

Table 2. Factors considered for site selection for cold storages

	Layers	Desirability for new cold storages-	Zonation (10 to 1) formed
1.	Existing cold storage	As far as possible from the existing cold storages	140, 120,100,80,40,20,10,5, 2, 1 km
2.	Crop map	Near to cropped areas	1, 5, 10, 20, 50, 70, 100, 150, 200, 280 km
3.	Transport	Near to availability of transport	1, 2, 5,10, 15, 20, 30, 40, 50, 100 km
4.	Agriculture markets	Nearer to Agriculture markets	1, 2, 3,4,5,6,7,8,9,10 km
5.	Land Use (non-agriculture)	8 classes were formed, the first class was ranked as 10.	i. Other wasteland ii. Scrubland iii. Gullied iv. Grassland v. Build up/Scrub/Deg. forest vi. Evergreen forest/Deciduous forest vii. Current fallow/Plantation/orchard viii. Kharif only/Rabi only/Zaid only/Double / triple cropped /Water body
6.	Electrification	Where electricity is more	55-63, 50-55, 40-50, 30-40, 20-30, 15-20, 10-15, 5-10, 0-5, 0
7.	Ground water	Ground water is more	
8.	Elevation	At lowest elevation from MSL	34-50 50-70 70-100 100-130 130-150 150-180 180-200 200-230 230-250 250-300 m
9.	Vulnerability to earthquakes	As less damage risk as possible	Low risk zone II Moderate risk zone III High risk zone IV
10	Rivers and wetland	These areas would not be considered at all	Constraint
11	Sandy soil		Constraint
12	Drainage		Constraint (Poor Drained soils)
13	Built up		Constraint
14	Areas within 25m of road/rail		Constraint
15	Slope >30%		Constraint
16	25m areas around farm lands		Constraint

3.2.9 **Elevation:** Elevation determines the level of land below and above sea level. Low lying areas below 2.5 meters are prone to flooding, which is why it is assigned low weightage. Between 2.5 to 5 meters is considered best for any land use, beyond 5 meters it becomes relatively not so desirable.

3.2.10 **Earthquake hazard:** Areas prone to earth quake were assigned lesser value.

3.2.11 **Constraints:** Seven factors were considered are constraints, i.e. the area of these factors would not be desirable for erecting a cold storage structure.

1. Area under these factors were masked out of the study area to arrive at the final outcome map.
2. Buildings: Ideally no new building should be proposed within 6m from an existing building. Since the study is at state level, there are numerous units to be taken care of. Thus, the built-up area will be considered and extracted out from the output as it is. The 6m buffer around building will be considered when the study will be done on a finer scale.
3. Slope: Areas with slope more than 30^0 was not at all considered for the study. Thus they were masked out of the study area.
4. Drainage: When asked to engineers, they opined that areas with poor drainage should be avoided for any kind of construction (Kumar and Bansal).
5. Soil texture: Areas with sandy soil was also masked out since it is not good for constructions
6. Rivers and wetlands: Areas around rivers and wetlands were also masked out to avoid suggested sites falling on water bodies.
7. Transportation network: Areas within 4.25 m of road and rail network were also masked out and not included for the analysis.

3.3 **Establishing weight of factors:** Analytical Hierarchy process (AHP): This is one of the most widely used method used for multi criteria decision making process. It involves both subjective human judgments and objective evaluation by Eigen vector and examines the consistency of the evaluation by Eigen Value. A matrix was constructed, where each criterion was compared with the other criteria, relative to its importance, on a scale from 1 to 10, where 1 = equal preference between two factors; 10 = a particular factor is extremely favored over the other. 9 factors were considered for the analysis out of total 16, and the remaining 7 factor areas were extracted out of the study. The weightage given to various pairs of criteria used for the study is given in Table 2.

Table 3. Matrix for pair-wise comparison of criteria

Factors	Cold storage	Farm site	Transport	Mandis	LULC	Electrification	Groundwater	Elevation	Earthquake
Cold storage	1.00	1.00	1.00	6.00	4.00	1.00	3.00	4.00	2.00
Farm site	1.00	1.00	2.00	8.00	4.00	2.00	3.00	5.00	3.00
Transport	1.00	0.50	1.00	7.00	5.00	1.00	3.00	4.00	2.00
Mandis	0.17	0.13	0.14	1.00	0.50	0.14	0.20	0.20	0.20
LULC	0.25	0.25	0.20	2.00	1.00	0.20	0.33	1.00	0.25
Electrification	1.00	0.50	1.00	7.00	5.00	1.00	3.00	4.00	2.00
Groundwater	0.33	0.33	0.33	5.00	3.00	0.33	1.00	2.00	0.50
Elevation	0.25	0.20	0.25	5.00	1.00	0.25	0.50	1.00	0.25
Earthquake	0.50	0.33	0.50	5.00	4.00	0.50	2.00	4.00	1.00
Total	**5.50**	**4.24**	**6.43**	**46.00**	**27.50**	**6.43**	**16.03**	**25.20**	**11.20**

Table 4. Calculation of weights of factors

Factors	Cold storage	Farm site	Transport	Mandis	LULC	Electrification	Groundwater	Elevation	Earthquake	Weightage
Cold storage	0.18	0.24	0.16	0.13	0.15	0.16	0.19	0.16	0.18	**0.170**
Farm site	0.18	0.24	0.31	0.17	0.15	0.31	0.19	0.20	0.27	**0.224**
Transport	0.18	0.12	0.16	0.15	0.18	0.16	0.19	0.16	0.18	**0.163**
Mandis	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.02	**0.020**
LULC	0.05	0.06	0.03	0.04	0.04	0.03	0.02	0.04	0.02	**0.037**
Electrification	0.18	0.12	0.16	0.15	0.18	0.16	0.19	0.16	0.18	**0.163**
Groundwater	0.06	0.08	0.05	0.11	0.11	0.05	0.06	0.08	0.04	**0.072**
Elevation	0.05	0.05	0.04	0.11	0.04	0.04	0.03	0.04	0.02	**0.045**
Earthquake	0.09	0.08	0.08	0.11	0.15	0.08	0.12	0.16	0.09	**0.106**
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	

A weight estimate is calculated and used to derive a consistency ratio (CR) of the pairwise comparisons. If CR > 0.10, then some pairwise values need to be reconsidered and the process is repeated until the desired value of CR < 0.10 is reached. Saaty suggested a threshold of 10% for the CR values. He believes that the threshold of CR is analogue to significant level of statistical analysis that is related to confidence level of the analysis rather than a fixed value that everybody must follow. Various parameters to arrive at CR value is given below –

λ_{max} = 0.17*(1/0.18) + 0.224*(1/0.24) + 0.163*(1/0.16) + 0.02*(1/0.02) + 0.037*(1/0.04) + 0.163*(1/0.16) + 0.072*(1/0.06) + 0.045*(1/0.04) + 0.106*(1/0.09) = 9.4

Consistency Index (CI) = λ_{max} – n/(n – 1) = 9.4-9/(9-1) = 0.0501

Random consistency Index (RI) (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	**10**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	**1.51**

Consistency Ratio (CR) = CI/RI = 0.0501/1.45 = 3.46 < 10% (Acceptable)

3.4 **Interaction of GIS layers of factors:** The final output i.e. the map showing the sites selected for cold storages in order of various preference is arrived at using the formula –

$$S = \Sigma w_i \times \Pi c_j \quad (1)$$

Where:
S – is the composite suitability score
wi – weights assigned to each factor (Ref table 4)
cj – constraints (or Boolean factors)
Σ -- sum of weighted factors
Π -- product of constraints (1-suitable, 0-unsuitable)

The formula was applied to all the raster layers using ArcGIS software. Applying the above formula using GIS raster factors will be –

Output = ((Cold Storage * 0.170) + (Farm site * 0.224) + (Transportation * 0.163) + (Mandis * 0.02) + (LULC * 0.037) + (Electrification * 0.163) + (Groundwater * 0.072) + (Elevation * 0.045) + (Earthquake * 0.106)) * Sandy soil *rivers* Poor drainage * Built up * 25m buffer around roads * Steep slope * 25m buffer around farms

4. RESULTS AND DISCUSSION

Use of AHP takes care of both - human choice as well as the quantification of the factors. While the researcher has to only decide the weightage between pairs of parameters, the process helps to rank the factors amongst them. Farm site has emerged as the most important one with weightage of 0.224 followed by existing cold storages, which is a very important parameter to judiciously select sites where they are most required. The ranks of the factors obtained from AHP is as given below –

1. Farm sites
2. Existing Cold storages
3. Transportation and electrification
4. Earthquake zone
5. Groundwater
6. Elevation
7. LULC

Figure 2 shows outputs obtained during processing at various stages of the study. It is very clearly noticeable that the process has taken into account the rank of the factors. It is easily noticeable that the favorable sites for cold storages as indicated by the process are nearer to the farm sites, at electrified areas, and at safer earthquake zones.

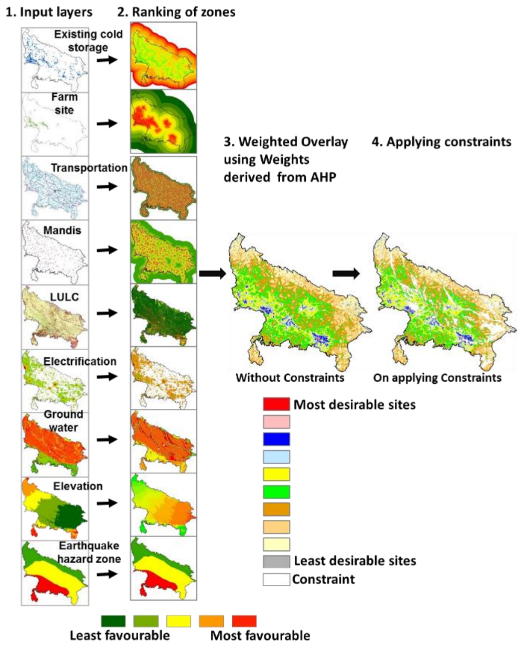

Figure 3. Analysis of factors for site selection of cold storages

Case Study: For the purpose of better and minute understanding, one district was taken up. Agra is one district where potato is grown on a large scale. High suitability areas for cold storages for Agra falls in the zones where there is availability of transportation and/or electrification and/or area falling in low earthquake damage risk zone. Use of constraints helped the study considerably in avoiding areas like water bodies or built up areas, thus enhancing the applicability of the outcome. In Agra, areas in built-up areas also fall in high suitability areas for cold storages. But on practical grounds such areas could not be used for building cold storages.

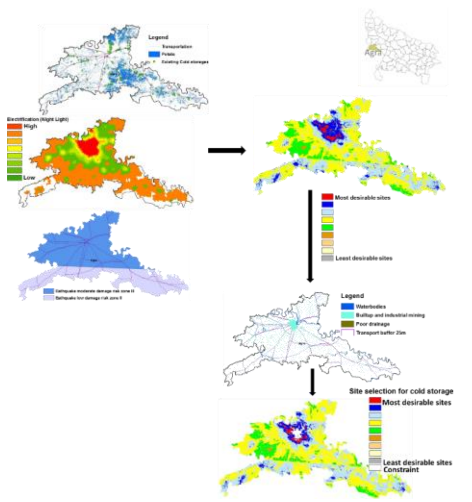

Figure 4. Application of factors and constraints on Agra district

Similarly the site suitability of the whole state (figure 4), seems to fall near the regions having potato producing areas and/or, having high electrification and/or good transport facilitties available. Thus, districts of Gautam Budh Nagar, Aligarh, Mathura, Agra, Firozabad, Mainpuri, Etawah, Auraiya, Kanpur, Allahabad and Barabanki have high suitability areas. Out of these, even though districts like Gautam Budh nagar, Kanpur, Auraiya and major part of Allahabad does not have potato growing regions are classified as high suitability regions due to availability of electricity, transport and proximity to the potato growing regions.

Bhimnagar (refer figure 5) on the other hand has considerable area under potato crop, but due to its location falling under high earthquake damage risk zone, the suitability for building cold storages has diminished in that district.

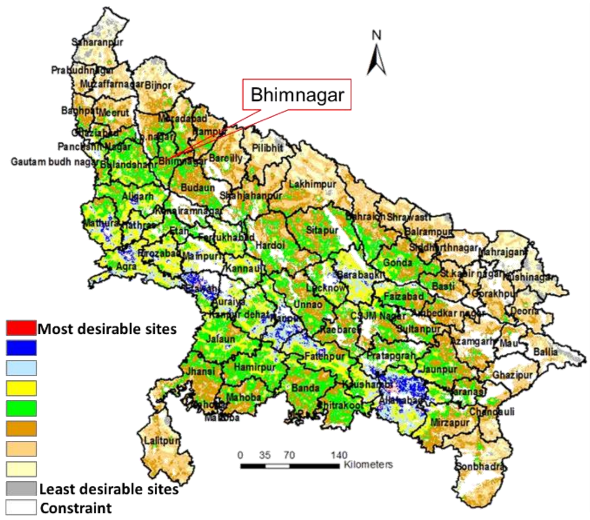

Figure 5. Site suitability for cold storages for the state of Uttar Pradesh

5. CONCLUSION

The decision of inclusion of criteria and alternatives are very subjective. There can never be an exhaustive list of criteria in any said study. Similarly, there is no correct or incorrect criterion because it is subjective to the opinions of the researchers or managers of a project. Given a final objective, criteria can be added or removed, depending on persons involved, and the extent of information available to the people about the said project or the extent of the detailing required by the project. For example, if such a study needs to be done on a block or a region level, there could be many factors that need to be included further, like sub-soil dispersion system, open spaces around existing buildings, etc. On the other hand, many factors might become unnecessary, like earthquake risk zone, ground water status as the whole study area might not have several categories. Some factors may be combined together or disintegrated into various parameters. In this study, only the Sandy soil is used for the study among all kinds of soil textures. Having said that, it cannot discount exclusion of important criteria. The current study highlights the importance of taking into account of various factors for arriving at a particular decision. Thus it is crucial that, for such a project, relevant literature need to be exhaustively referred. Secondly, this study showcases the utility of GIS software for handling such complex multi criteria projects. GIS helps the user to create multiple buffer zone indicating various distances from a given structure. It can allocate ranks with the help of ‘value’ of various parameters. Also, GIS has the provision of assigning percentage influence for each layer for integrating all the factors with appropriate weightages and for computing the weighted outcome. Lastly, the process of AHP effectively helps us to decide, the weightages of various alternatives in such a complex environment. In a multi criteria environment, all the participating factors cannot have same weightage or importance. Thus ranking among factors is necessary, which the AHP does in a very fair manner.

6. ACKNOWLEDGMENT

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7. REFERENCES

Department of Horticulture and food processing, Uttar Pradesh, 2014. “The Uttar Pradesh Potato development policy – 2014”

Miller W, Collins W, Steiner FR, Cook E (1998) An approach for greenway suitability analysis landscape and urban planning. Int J Geogr Inform Sci 42(2–4):91–105

National Building Code of India, 2005. Bureau of Indian Standards, New Delhi-110002.

Satish Kumar and V.K.Bansal, 2016. A GIS-based methodology for safe site selection of a building in a hilly region. Frontiers of Architectural Research (2016) 5, 39–51.

Eastman JR (2003) IDRISI Kilimanjaro: guide to GIS and image processing. Clark Laboratories, Clark University, Worcester, pp 328

Saaty, T L (1980). The Analytic Hierarchy Process. New York: McGraw Hill**.**