GIS-Based Factor Identification for the Change in Occurrence of *Genista pilosa*: a Case Study in Southern Sweden

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Abstract

This study has the objective of identifying the possible environmental constraints that has role for the continuous loss of heathland plant *Genista pilosa*. The study has assessed different environmental settings where the plant occurs by way of overlaying analysis based on multiple spatial data sets. Thereafter empirical change detection analyses on the land use of the study area have been performed on the GIS environment by combining temporal based remotely sensed spatial data. The result was then analyzed using land use dynamicity model and the rates of change on each land use type are identified. Expansion of human activity, especially the spreading of agricultural land and urbanization, is found to be the most determinant factor for the dramatic loss of the plant. Finally serious attention for the protection of the plant is recommended by mentioning the possible problem that would occur due to a loss of biodiversity.

**Keywords:** Genista pilosa, Overlaying analysis, Change detection analysis, GIS, Dynamicity model.
Preface

This was a 15 week study and meant for the accomplishment of a masters level study in Geomatics. Different individuals and parties have made contribution to make this study feasible; I would like to express my gratitude to Jenny Pettersson for assisting me in compiling and technical advising for handling of the data used in this study. I also want to thank Professor Nils Ryrhholm for providing the plant species data and giving all needed information regarding the biology of *G. pilosa* from biologic point of view. In addition I would like to thank Swedish governmental organizations and others referred in the study for providing necessary spatial data used that were essential for the accomplishment of this study.
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1. Introduction

Biodiversity is an essential component of nature that keeps the environment balanced and makes life run continuously on the basis of mutual interdependence of plants and animals. The existence of different varieties of plant, animals and organisms would create a balance depending on each other for survival. Especially plants are a base of all biotic environments since they are a primary source of food. Unless the sustainability of biodiversity is maintained by giving necessary attention for the protection and conservation of the environment, our planet would face a serious and multiplicative problem. The conservation, enhancement, sustainable and equitable use of biodiversity should be given high priority in all national environmental protection programs (Swaminathan, 2003). In order to attain such goal a proper use of information of the environment is needed. In this, Geographical Information System (GIS) plays an important role as a tool for environmental management, with the current greater concern for sustainable use of resources, and conservation and monitoring of biodiversity (Salem, 2003).

‘Biological monitoring’ is a term explaining the usage of organisms to indicate as well as to assess an ecological degradation or an improvement, due to a specific cause (pollution or degradation both natural and biotic, including anthropogenic) at a specific or at similar locations, with minimal use of equipment at the field level by non-specialists (Swaminathan, 2003). In spite of the complexity of nature and interaction of environmental entities, there should be a means of handling information regarding the environment. Salem (2003) stated that information needed for biodiversity are of many kinds; any database that deals with biodiversity information has to be geographically based, and able to predict where new populations of endangered species with a limited known range might be expected, indicating potential hot spots.

The importance of analyzing spatio-temporal characteristics of land use cover change (Zhang, Kang, Wang & Sun, 2010) is essential for understanding pattern and provides vital information for decision making. Regarding a cultural landscape change, Bender, Boehmer, Jens & Schumache (2005) have tried to analyze and quantify the change of landscape using methods that were derived from geographical landscape change analysis, but based on cadastral maps and land registers, and by rendering at a land plot level by the use of GIS. The quantitative measure of a land use change was calculated by Zhu, He & Zhang (2001), by way of land use dynamicity in a same way to this study and the result explicitly shows temporal variation in each class of land use type in accordance with the time span the evolution took place.

Since human beings are struggling for survival, their use and exploitation of resources is normally based on the natural environment. As described by Farle, Revah, Atkinson & González (2011), human activities such as forest clearing, agriculture, farmland intensification and expansion of urban centers are examples of the many ways that human land uses have altered the world’s landscapes. The process of land use change is not actually sole dependent on the anthropogenic factor; it is also driven by biologic process that is characterized by geographical spreading of biotic features. Land-use change is fundamentally a spatial process,
resulting from the collective outcome of myriad processes: socioeconomic, institutional, biophysical and ecological (Munro & Muller, 2007). This scenario is common everywhere though the scale of the problem vary from place to place. In this, there is a strong need to better understand the dynamics of the feedback mechanisms that relate environmental pattern to social process. Anthropogenic changes in land use and land cover are being increasingly recognized as critical factors affecting global change (Nagendra, Munroe & Southworth, 2004).

*Genista pilosa* (Hårginst in Swedish), is one of the rare and endangered heathland plant species in the Genista family (Tsaliki & Diekmann, 2011). Regarding its geographical distribution, it predominantly occurs on parts of north, east and central Europe (Greinwald, Rensen, Veit, Canto & Witte, 1995). It is believed that the plant serve as a conducive habitat for more than twelve different species of moths (insects of the order Lepidoptera, generally distinguished from butterflies by their nocturnal activity, hairlike or feathery antennae, stout bodies, and the frenulum that holds the front and back wings together). It is a dwarf bush plant with yellowish flowers (figure 1).

![Figure 1. Genista pilosa (Photograph by Anderberg (1996)).](image)

Particularly in Sweden, the plant is showing a considerable change in its distribution and population size for the last 50 years. Since the 1950’s, the plant has been disappearing by a higher rate and the consecutive surveys on the plant is proving its continuous extinction. The population size data of the host plant have been gathered for many years since 1800. Since 1880, a total of 203 sample points have been surveyed at different time interval; during these periods the field survey did not cover all areas that were covered by the host plant. But in 1997 and 1998, a crew of botanists in Sweden have carried out a comprehensive research in the southern part of the country and surveyed each pocket location covered by the host plant except some spot areas around southern part of the study area, by that time this plant was abundant covering isolated areas at the south-western tip of the country. But after a decade, in 2008, biologists using their field observation delineate areas on existing map where it was
believed there was an occurrence of *G. pilosa*. The new data showed that the population of *G. pilosa* was considerably shrinking in the area where it used to occur densely. This scenario grasps the attention of biologists and environmental scientists concerning that the plant could totally vanish in the future unless some measure is taken.

Though there are not many studies carried out on the plant, a previous study by Tsaliki and Diekmann (2011) have shown that the plant is found on areas where there is a relatively high temperature and low rain fall. Regarding the problem the plant is facing, Tsaliki and Diekmann (2010) have tried to see from the point of view of habitat fragmentation in combination with soil quality which is another insight for the problem the plant is facing. In addition, Greinwald et al. (1995) have analyzed the alkaloid pattern of eleven plant species in the *Genista* family including *G. pilosa* with empirical research of laboratory test and reveal the accumulation of *α*-pyridone alkaloid (an alkaloid which is mostly common on plants that grow on acidic soil) in *G. pilosa*. The acidic nature of the soil presumably gives initial information about the behavior of soil the plant is growing on since the soil behavior has a lot to do with a variety of environmental factors.

Considering the above problem *G. pilosa* is confronting, this study has objective of:

i. Making a GIS-based assessment on the major environmental problem the plant is facing to spread and cover a much larger area or at least maintain its original extent.

ii. Examining the environmental factors that are assumed to be important and have a role in the distribution and occurrence of the plant.

In order to attain the objective of the research, a GIS based overlaying analysis using different environmental input data sets will be carried out. Thereafter change detection analysis will be applied to analyze the evolution of the study area’s land use pattern and the magnitude at which each land use parcels (classes) are transformed. The rate of change on the land use will be analyzed using dynamicity algorithm for each class and later analyzed on frequency distribution. The study is believed to give initial information for biologists about the behaviour of the plant from the context of the habitat it grows abundantly and the constraints hindering the plant from expanding. In addition, this study aims to point out important measures that should be taken in order to protect this endangered plant species before it completely vanishes.
2. Study Area

2.1. Extent of the study area
The study area of this research is located at the south-western part of Sweden, with geographical extent N 56° 02’ 10’’ - N 57° 10’ 59’’ and E 12° 11’ 40’’ - E 14° 00’ 47’’ respectively. The boundary used for this study is delineated arbitrarily considering much larger area outside of the host plant coverage which incorporate five administrative provinces i.e. Halland, Skåne, Kronoberg, Jönköping and Västra Götaland (see Figure 2). The particular areas where G. pilosa used to grow and still does are within the larger geographical frame used as a study area. The arbitrary delineation of the larger study area is based on an assumption that it would serve as a base of comparative measure of the trend in the temporal modification of landscape; this will be done with respect to the isolated spots of the plant coverage in addition to the scope of its environmental settings.

Figure 2. The study area and its administrative provinces. (Data: © University of Gävle).

2.2. Temperature
Rates of ecological processes are usually influenced by temperature. For simplicity and efficiency of ecosystem models it is often necessary to summarize information about temperature dependence from short, e.g. hourly, time intervals over longer, e.g. monthly time periods i.e. to calculate long term expected values of dependence functions (Lischke, Löffler...
The average annual temperature of the study area was manipulated based on the decision made by World Meteorological Organization (WMO, 1992) that the statistical parameters used for climate descriptions must be calculated for the so-called normal periods. Normal periods are usually 30-year periods, where in this case 1961-90 is the current standard normal period that is used for this study. The data covered the whole Sweden and therefore it was cropped using the boundary extent of the study area. The map (figure 3) was available in raster format so that it was digitized and classified in accordance with the legend of the original data.

Figure 3. Average annual temperature in °Celsius: (source: SMHI, 1961-1990).

2.3. Rainfall
The average annual rainfall data was acquired for the normal period 1960-90; that is set by World Meteorological Organization (WMO, 1992). The raster map was cropped and digitized holding the information on the legend (see figure 4).
2.4. Soil

The soil data from Swedish Geological Survey (SGU, 2011) had numerous attributes that describe the different types of soils in the study area. It was classified using the type of soils and projected in the way matching the study site. The attribute of the data was detailed and was in Swedish; proper scientific translations were therefore made and labeled accordingly. Note that the data does not cover all the study area but part of it where most of buffered points that the plant *G. pilosa* is found; which is the main intention of this study (see Figure 5). In addition, the soil data had some isolated blank values that did not affect this study due to the fact that it was not falling in the buffered region.
Figure 5. Soil types of the study area: (source: SGU, 2011).
3. Materials and Methods

3.1. Materials

For the accomplishment of this study different spatial data of various formats were needed for specific purposes. Including administrative map of Sweden, digital elevation data, soil data, climatic data and time series satellite imageries were compiled from respective sources mentioned below (table 1):

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>File format</th>
<th>Quality (resolution)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative map</td>
<td>Länsstyrelserna (2009)</td>
<td>ArcView shape file</td>
<td></td>
</tr>
<tr>
<td>Digital Elevation Model</td>
<td>Consortium for Spatial Information (CGIAR-CSI, 2008)</td>
<td>ARC ASCII</td>
<td>90 meter resolution</td>
</tr>
<tr>
<td>Soil map</td>
<td>Geological Survey of Sweden (SGU, 2011)</td>
<td>ArcView shape file</td>
<td>5 meters resolution and less than 10 meters error in positioning of digitization</td>
</tr>
<tr>
<td>Average annual precipitation and Average annual temperature</td>
<td>Swedish Meteorological and Hydrological Institute (SMHI, 1961-1990)</td>
<td>TIFF</td>
<td></td>
</tr>
<tr>
<td>Satellite imagery for the year 1999-2000</td>
<td>Landsat.org (2011)</td>
<td>TIFF</td>
<td>30 meter</td>
</tr>
<tr>
<td>Land use map for the year 2008</td>
<td>National Mapping Authority of Sweden (2008)</td>
<td>TIFF</td>
<td>10 meter</td>
</tr>
</tbody>
</table>

In order to handle all data and conduct the desired analysis, different softwares were used for specific tasks. FME (Feature Manipulation Engine) was used for transforming data with different coordinate systems into one system that is used for this study. Erdas Imagine 9.3 was used for recoding and classification of raster data and satellite imagery respectively. In addition, ArcGIS 10 was used for all analysis carried out on throughout the study.

3.2. Methods

3.2.1. Coordinate transformation

As the spatial datasets are gathered from different sources, the alignment of maps; in particular the coordinate systems, was a necessary procedure for map overlay. Since coordinate transformation and georeferencing are similar procedures for the alignment of maps, the coordinate transformation or the georeferencing process plays an important role for the operations of map overlay (Chiu & Wang, 2003). In order to view and analyze all the data used on a same viewer; the data was synchronized with one coordinate system. Note that some of the data gathered were in RT_90 coordinate system which until recently was a
common spatial reference system used for most spatial datasets in Sweden. Other data were in SWEREF_99 coordinate system that is used currently. All data with SWEREF_99 system were transformed to RT_90 coordinate system since most of the data were in RT_90 format.

3.2.2. Plotting of surveyed points
The initial data that was surveyed by botanists in 1997 and 1998 using global positioning system (GPS) and shows each pocket locations used to be covered by G. pilosa and the later data that was derived from existing map by picking the central points of areas covered by G. pilosa. Both datasets were then plotted as point data in order to display spatially and make ready for further analysis (figure 6). As can be seen on figure 6 of plotted points, the plant has considerably reduced in its population size and areal coverage compared to its former coverage. Statistically, a total of 971 sample points have been surveyed in the successive years of 1997-98. This numerical figure has dramatically dropped to 39 within a decade after the first points were gathered. Note that those 39 points are where moths are believed to be found; there might also be some small non-moth G. pilosa species in between the plotted points.

Figure 6. Plotted points showing areal distribution of G. pilosa observations at different time. A) In 1997-1998, and B) In 2008.

3.2.3. Buffering of the plant coverage
As mentioned in the introduction section, there are two datasets for the plant; the one surveyed on ground in the year 1997 and 1998 and the later derived from existing map in 2008. For this study, the 2008 data was used in comparison to the older data to analyze the
possible problems regarding the continuous shrinking of the plant occurrence. In order to analyze the data using other spatial datasets, all 39 sample points of the 2008 data were buffered using their average areal coverage since the original data was derived using the central point of each parcel. In this, the area of each sample points was calculated by way of averaging the total area to the number of sample points (see equation 1). Note that the parcel areas covered by the plant *G. pilosa* were irregularly shaped.

Area calculation

\[
\frac{\text{Total area of sample points}}{\text{Number of sample points}} = \frac{2,316,083 \text{ m}^2}{39}
\]

\[= 59,386 \text{ m}^2, \ 244 \text{ m} \times 244 \text{ m area}\]

From this, the length of each side of an individual parcel was made to be 244 m; taking half of this figure as a radius, the sample points were buffered as a circular polygon with a regular shape (see Figure 7 & 8). Tsaliki and Diekmann (2010) on their study conducted in Germany also analyzed the maximum patch size of each *G. pilosa* populations to be 424 x 424 m which do not deviate much from the result of the average areal calculation of this study.

![Figure 7. Buffering distance of the plant’s coverage.](image)

(Equation 1)
Figure 8. Sample points buffered with 122 meter radius.

3.2.4. DEM Processing

3.2.4.1. Masking and conversion of file format
In order to explore the full value of any spatial data, the appropriate information has to be extracted and presented in standard format to import it into geo-information systems and thus allow efficient decision processes (Benz, Hofmann, Willhauck, Lingenfelder & Heynen, 2004). The original elevation data which was in ARC ASCII format was covering much larger area outside of the particular study area. Thereafter, it was masked using the boundary of the study area. After adjusting the extent and coordinate system of the original ASCII format elevation data, it was then converted to feature dataset format in order to make it ready for further interpolation process; after converting, the XY coordinates and elevation values on the ASCII file was made up of 2,346,395 points = 5 points per meter square.

3.2.4.2. Interpolation
Consideration of topographic nature is important since it directly or indirectly affects all other environmental settings. Topographic conditions are key factors determining species distribution (Kobayash & Koik, 2010). The most important characteristics of the topography of the study area were analyzed by using the digital elevation data.

The point data which has the elevation information of the study area was then interpolated using an Inverse Distance Weighted (IDW) method since there were too many known points to analyze pattern. IDW interpolation method is one of the most frequently used deterministic models in spatial interpolation also it is relatively fast and easy to compute, and
straightforward to interpret. Its general idea is based on the assumption that the attribute value of an unsampled point is the weighted average of known values within the neighbourhood, and the weights are inversely related to the distances between the prediction location and the sampled locations (Lu & Wong, 2008). The resulting digital elevation model (see figure 9) shows a realistic land feature and the elevation ranges from -1 meter to 239 meter above mean sea level.

Figure 9. Digital elevation data (in meters) interpolated using IDW method (0.004 m cell size).

3.2.4.3. Slope and aspect
The slope of the study area was derived from the interpolated digital elevation data. The resulting slope map shows that most of the study area has a flat topography (see Figure 10). In addition, the aspect of the terrain was derived in order to analyze the orientation of the ground (see Figure 11). This is because vegetation distribution in mountains of temperate regions is strongly influenced by aspect (Aguirre, Ortiz, Zamorano & Reyes, 2007).
Figure 10. Slope of the study area in degrees.

Figure 11. Orientation of the study area.
3.2.5. Land use (late 1990’s)
For the assessment of the study area’s land use pattern in the late 1990’s, Landsat TM Imagery over the study area was downloaded. The study area is covered with two successive imageries: Path 195 020 and 195 021 that were taken on September 11, 1999 and May 8, 2000 respectively (see Appendix 1). Beside its spatial resolution, the imagery is characterized by its high spectral resolution.

3.2.5.1. Layer stacking and Image mosaicking
Both satellite imageries had seven informative bands which was separately stored in the database. In order to analyze as one multiple band imagery, all bands in both images were made to be stacked each other (see Appendix 2). The two successive imageries were needed to be coincided each other so as to form a continuous spatial pattern. As a result, a mosaic of images was done and projected together to make ready for further analysis (see Appendix 3: A, B and C).

3.2.5.2. Image classification
One of the widely accepted applications of pattern recognition techniques to image spectral interpretation is the multispectral classification (Zaki, Eltohamy & Hassan, 1995). Using the Landsat TM false color composite band combination (band 4, 3, 2), supervised classification was performed by applying training sites. Thereafter the accuracy assessment was analyzed to make sure the classification reflects the ground truth: and the result (85.96 % total accuracy) was found to be satisfactory (see table 2). After merging of all pixels that had the same land use type on the signature editor, all unclassified pixels was recoded with zero value in order to exclude from labeling each information classes as unique land use type. Thereafter the imagery was classified and labeled using the six land use information classes (see figure 12).

Table 2. Accuracy assessment result for supervised classification.
3.2.6. Land use (2008)
A relatively recent land use map which was prepared by National Mapping Authority of Sweden (2008) was downloaded and classified on Erdas Imagine environment using the legend available in a separate document. The legend had many classes and sub classes that had to be synchronized to fit with this study. In this, the numerous classes in the original data were generalized into six major land use types (see table 3) to analyze it together with the previous land use pattern of the area. Thereafter, the land use map of 2008 was constructed (see figure 13).
Table 3. Generalized classes and sub classes of the land use data.

<table>
<thead>
<tr>
<th>Classes and sub classes on the original land use data</th>
<th>Generalized as</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense urban structure, sparsely populated urban structure, communities with more than 200 inhabitants, small areas of gardens and green spaces, larger areas of gardens and green spaces, towns with less than 200 inhabitants, industrial, commercial entities, public service, military camp, sand transport units, public service and military barracks, road and rail networks with surrounding areas, harbours, air fields, mining sites, landfills and construction sites, mineral extraction places, gravel and sandpit, other mineral extraction sites, land fill, built up places, landscaped, not farming, vegetated areas urban green spaces, sports and recreational areas, sports complex, shooting range, motor car and an equestrian facility, dogs track, aerodrome (grass), trail, golf course, campground and recreational.</td>
<td>Urban area</td>
</tr>
<tr>
<td>Arable land, permanent crops, fruit and berry, pastures, landscaped areas, agricultural areas.</td>
<td>Agricultural land</td>
</tr>
<tr>
<td>Forests, deciduous forests, deciduous forests in the marsh, deciduous forest on the mountain of day, coniferous forest, coniferous forest on lichen fields, coniferous forest 5-15 m, coniferous forest &gt;15 m, coniferous forests in the marsh, coniferous forest on the mountain of day, mixed forests, mixed forests on peat land, mixed forest on the mountain of day, shrub and / or herbaceous vegetation, natural grassy marsh, intermediate in forest-shrub land, young forest.</td>
<td>Vegetation</td>
</tr>
<tr>
<td>Open land with no or sparse vegetation, beaches, dunes and sandy plains, mountain of day and blocks of land, areas with sparse vegetation, fire field, glaciers and permanent snow fall.</td>
<td>Open area</td>
</tr>
<tr>
<td>Inland waters, rivers, lakes and ponds, lakes and ponds, open space, lakes and ponds, seawater, coastal lagoons, estuaries, coastal sea and oceans.</td>
<td>Water body</td>
</tr>
<tr>
<td>Freshwater wetlands, marshes, wet land, other wetlands, peat, salt affected wetlands, salt affected marshes.</td>
<td>Wet land</td>
</tr>
</tbody>
</table>
Figure 13. Classified land use map of study area for the year 2008.

3.2.7. Overlaying analysis
Map overlay is one of the most frequent tasks for research and practical application in fields such as urban planning, surveying, remote sensing and GIS (Chiu & Wang, 2003). After all different environmental factors were manipulated separately with wider geographical scope; each theme was analyzed in comparison with the area where the plant *G. pilosa* grows. In this, the spatial information that was stored in the digital elevation model, slope, aspect, temperature, rainfall, land use and soil map was overlaid on the actual (2008) plant coverage area to determine the possible environmental situation that the plant has managed to survive.

3.2.8. Change detection analysis
Cultural landscapes ultimately require manipulation with the help of a GIS in order to successfully manage the abundant information about land units, attribute data, and temporal layers. The GIS serves here predominantly to analyze the changes and to calculate the proportion of each land use type (Bender et al, 2005). Landscape change at a parcel level is believed to give dependable reason for the ongoing loss of the plant. Aiming at assessing the temporal change on the land use pattern of parcel areas where *G. pilosa* used to occur but vanish through time, the 1997-98 surveyed points were buffered with a same radius as the 2008 points. Thereafter 39 parcel areas that coincide with the 2008 data were excluded from being part in the data, since this study aimed at analyzing the possible factor for the lost ones. Finally the 1997-98 parcel areas were then superimposed on the land use map of 2008.
Both 1997-98 and 2008 plots that were derived using the field and laboratory surveyed points were analyzed in comparison with both classified land use maps. The magnitude of change in land use pattern was analyzed by applying zonal histogram of GIS spatial analyst. The comparative result on the graph is analyzed using the type of land use and in relation to its frequency of occurrence; stored as count value on the spatial datasets.

3.2.9. Land use dynamicity model
The rate of change on each land use type (class) was calculated using the temporal change of each land use type in comparison with time. The models can be used to compute the extent of dynamic change of various land use categories (Zhang et al, 2010). The single land use dynamicity can be calculated as equation 2 (Zhu et al, 2001).

The dynamicity model is

\[
K = \left( \frac{L_{Ub} - L_{Ua}}{L_{Ua}} \right) \times \frac{1}{t} \times 100\% \tag{Equation 2}
\]

where \( K \) denotes the dynamicity of one land use type over the given period, \( L_{Ua} \) and \( L_{Ub} \) denote the areas of one land use class at the beginning (moment \( a \)) and at the end (moment \( b \)) of the study period, respectively, and \( T \) stands for the time span from moment \( a \) to moment \( b \) which in this case is 10 years. If \( T \) is set to be multiple years, the value of \( K \) will be the annual changing rate of the land use class during the given period.
4. Results

4.1. Result of overlaying analysis
Environmental factor based overlaying analysis and change detection analysis using time series spatial datasets was carried out. Considering the environmental setting where *G. pilosa* is growing, it is observed that it grows on a limited range of environmental set up compared to the environmental scope of the general study area. The result of overlaying analysis as summarized in table 4 shows the suitable environmental settings that are suitable for the healthy growth of the plant.

<table>
<thead>
<tr>
<th>Theme (map)</th>
<th>Environmental setting of the general study area</th>
<th>Environmental setting of the plant (<em>G. pilosa</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM</td>
<td>-1 - 239 meter</td>
<td>24 - 191 meter</td>
</tr>
<tr>
<td>Slope</td>
<td>0 - 17 degree</td>
<td>0 - 5 degree</td>
</tr>
<tr>
<td>Aspect</td>
<td>Flat, north, south, east and west</td>
<td>South, east and west</td>
</tr>
<tr>
<td>Temperature</td>
<td>4 - 8 °C</td>
<td>6 - 8 °C</td>
</tr>
<tr>
<td>Rainfall</td>
<td>600 - 1200 mm</td>
<td>700 - 1100 mm</td>
</tr>
<tr>
<td>Land use (2008)</td>
<td>Agriculture, open area, urban, vegetation, water body and wetland</td>
<td>Open area, vegetation, and wetland</td>
</tr>
<tr>
<td>Soil</td>
<td>Block ground, fill, glacial grove silt - fine sand, glacial sand, mud, glacial river sediments, grove silt – block, glacial river sediment, gravel, sand, stone – brick, clay-silt, moraine, Silt, postglacial sand, wave sediment sand, fungi sediments grove silt - fine sand (postglacial, younger), fungi sediment, gravel (postglacial, younger), sand - boulders (postglacial, younger), talus, histosol, river sediments, coarse silt - fine sand, river sediments, sand, sand – block.</td>
<td>Sand, histosol, glacial river sediment, silt, filled soil</td>
</tr>
</tbody>
</table>

4.2. Result of change detection analysis
A major environmental constraint for the survival of *G. pilosa* has been identified from the analysis carried out using temporal land use data of the study area. The classified land use map from the Landsat imagery of late 1990’s and raster land use map of 2008 portray an extensive change in the cultural landscape driven by a variety of economic activities. The areal coverage of vegetation cover and open area has reduced generally in the study area but agricultural areas, urban and wetland have considerably expanded at a higher rate; shown in table 5. These trends (land cover change) in the general study area have found to be more aggravated particularly in the areas where *G. pilosa* has vanished. A complete loss of open areas and wet land identified beside to a considerable loss of vegetation cover: both are
replaced mainly by agricultural land and urban settlements. Those areas that were covered by open areas and wetlands are transformed to agricultural parcels and urban settlements (table 6). The only land use class that records zero rate of dynamicity is water body.

**Table 5. Land use dynamicity of the general study area.**

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Areal coverage (1999-2000), (m²)</th>
<th>Areal coverage (2008), (m²)</th>
<th>Dynamicity (K), (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1,506,443</td>
<td>3,117,405</td>
<td>10.7</td>
</tr>
<tr>
<td>Vegetation</td>
<td>10,626,752</td>
<td>8,427,836</td>
<td>-2.1</td>
</tr>
<tr>
<td>Wetland</td>
<td>326,778</td>
<td>544,446</td>
<td>6.7</td>
</tr>
<tr>
<td>Urban</td>
<td>74,871</td>
<td>447,235</td>
<td>49.7</td>
</tr>
<tr>
<td>Water body</td>
<td>713,284</td>
<td>713,284</td>
<td>0</td>
</tr>
<tr>
<td>Open area</td>
<td>8,165</td>
<td>6,087</td>
<td>1.2</td>
</tr>
<tr>
<td>Total</td>
<td>13,256,294</td>
<td>13,256,294</td>
<td>66.2</td>
</tr>
</tbody>
</table>

**Table 6. Land use dynamicity of the area where *G. pilosa* has completely vanished.**

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Areal coverage (1999-2000), (m²)</th>
<th>Areal coverage (2008), (m²)</th>
<th>Replaced by</th>
<th>Areal coverage of the new land use type (m²)</th>
<th>Dynamicity (K), (%) of prior land use class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open area</td>
<td>85,446</td>
<td>-</td>
<td>Agriculture</td>
<td>85,446</td>
<td>-10</td>
</tr>
<tr>
<td>Vegetation</td>
<td>40,202</td>
<td>11,693</td>
<td>Agriculture</td>
<td>24,422</td>
<td>-7</td>
</tr>
<tr>
<td>Wetland</td>
<td>1,102</td>
<td>-</td>
<td>Urban</td>
<td>4,088</td>
<td>-10</td>
</tr>
<tr>
<td>Total</td>
<td>126,751</td>
<td>11,693</td>
<td></td>
<td>115,058</td>
<td>-27</td>
</tr>
</tbody>
</table>

The general study area’s land use pattern is found to be dominated by vegetation and agriculture with almost no open areas (see figure 14). Wide range of human activity i.e. agricultural areas and urbanization spread out generally to the whole study area and particularly on areas where *G. pilosa* used to grow. Most land use types that were suitable for the plant growth i.e. open area, vegetation and wetland (see figure 15) are replaced by new land use types i.e. agriculture, urban and some vegetation covers (see figure 16). In contrary to the above mentioned results derived by the analysis made, unexpected and deviating result has also been seen; the land use type vegetation was considered to be an area where the plant could be found on the 2008 land use map (see figure 17) but some amount of areas that were generalized as constraint on the 2008 land use map was covered by vegetation cover. This implies that some vegetation types that are long enough might shade *G. pilosa* and act as an agent for the extinction of the plant.
Figure 14. Different land use types in 2008 with frequency (number of parcel counts) in the general study area.

Figure 15. Different land use types in 1997-98 with frequency (number of parcel counts) of the pocket areas where G. pilosa used to occur.

Figure 16. Different land use types in 2008 with frequency (number of parcel counts) of the pocket areas where G. pilosa has vanished.
Figure 17. Different land use types in 2008 with frequency (number of parcel counts) of the pocket areas where G. pilosa has still survived.
5. Discussion and Conclusions

The cultural landscape of the study area has been found to be very dynamic. Compared to the time span at which the landscape marks its evolution, the rate of change in its land use pattern can be said to be quite fast. With the increase in population and development human beings will modify the physical landscape at different scale. As part of an economically active region, the study area is characterized by extensive agriculture and urbanization. Concerning the land use type that was analyzed to identify suitable areas to find G. pilosa, the field study conducted while surveying the sample points suggest that the plant normally does not grow in a wetland area. But it grows on isolated spots of areas within wetland which are covered with sandy soil. These sandy soil areas are mostly found on hilly areas that are characterized by poor water holding capacity (see Appendix 4). This would have been clarified well in the study if better resolution imagery was used. Since the areas of these isolated sandy soils are ranging from 5-10 meter radius, imagery with 10 meter or finer resolution could have explored most of the hidden sandy areas.

Temporal based spatial information was used for the study with an assumption of ecological disruption due to landscape change. The application of time series geographical products like maps, imageries, aerial photographs, GPS data and other form of spatial information are vital for analysis of dynamic environmental scenarios. Depending on the area of study, the temporal resolution aspect of the data is most of the time a big concern. Similar to this study, Metternicht (2001) used successive Landsat TM imageries with a time difference of a decade to analyze the temporal and spatial changes of salinity of soil. Specially in the case where only a low geometrical resolution data is available which have biases such as minimum cell definition (Robbins, 1997), it is necessary to compensate with a better temporal resolution data to attain good result.

Change detection analysis as one of a wide application area of GIS is crucial for the proper management, investigation and information handling process of the dynamic environment. GIS technologies provide a possible means of monitoring and mapping the changes occurring in natural resources and the environment on a continuous basis (Siddiqui, Jamil & Afsar, 2004). This can be regarded as a main application area that cope up GIS with environmental features that are in process and dependent with time; like land cover and land use change, weather analysis, crop status investigation and so on. For example Al Kuwari and Kaiser (2011) used Image data obtained through remote sensing by integrating with data collected from topographic, morphologic maps and field investigations in order quantify the land use/land cover changes which affect a shift (change) on a shore line of a sea. Concerning with land cover and land use change, the magnitude of change can be analyzed and manipulated in different way. The dynamicity model forwarded by Zhang et al (2010) and Zhu et al (2001) and used by this study is not a sole method but can be applied on any other analysis that aimed at identifying the share in change of each land use types as described by (Bender et al, 2005). Integrating GIS and remote sensing provided valuable information on the nature of land cover changes especially the area and spatial distribution of different land cover changes (Shalaby and Tateishi, 2007).
The dynamicity of cultural landscape has found to be rapid and extensive since the data used for the analysis had a time difference of one decade. The possible cause for the ongoing areal reduction of *G. pilosa* and other small plant species could vary from place to place depending on the nature and other local variables. Another recent study on *G. pilosa* conducted by Tsaliki and Diekmann (2011) point out the effect of insufficient pollination accompanied by reduced fruit and seed set. Beside cultural landscape change and habitat fragmentation, another approach which incorporate habitat fragmentation and soil quality have been analyzed by Tsaliki and Diekmann (2010) and soil measurements done on the plant reflect the highly acidic and nutrient-poor environment of the heathland fragments. In this, the feasibility of applying fragmented landscape model in GIS to study the linkage and relationship between altered geographical regions is important. Stressing the woodland loss or gain can be visualized quickly through the creation of altered landscapes. Swetnam, Ragou, Firbank, Hinsley & Bellamy (1998) have illustrated the generic feature of GIS tool in analyzing a fragmented landscape of woodland. Thanks to the growing science and technique of Geo-information, Landscapes changes and fragmentation problem nowadays can be quantified and assessed with landscape metrics applied to the satellite image and GIS mapping products even though the method and approach of its application could vary. Hansen, Franklina, Woudsmaa & Peterson (2001) analyze patch abundance, patch density, edge density, interspersion mean patch size, patch size variation, patch shape, proximity and core area by calculating Mean Patch Size, Patch Size Coefficient of Variation and Mean Proximity indices. In the same fashion, another study by Jorge and Garcia (1997) assessed habitat fragmentation by driving the above mentioned entities but in a more explicit way adding some more functions like fractal dimension and shape diversity index. Such approach seems to be more viable and dependable in giving a closer look of the situation on the ground.

Tsaliki and Diekmann (2010) have also assessed the relationship between the plant’s population size with pollinator visit and concluded the minimal effect of population size on *G. pilosa* case. Greinwald et al. (1995) homogenized the dry plant material in 0.1 N H$_2$SO$_4$ and revealed the accumulation of α-pyridone alkaloid in *G. pilosa*. Analyzing alkaloid of the soil content as affecting the survival and health of any plant, the approach was worth effective. The study area as part of economically active environment, the cultural landscape has been influenced by an enormous urbanization process; the phenomenon of urban development is one of the major forces driving land use change (Wu et al. 2006).

The spatial analyst tool of GIS is found to be very effective in analyzing spatial pattern and inter-relationship between different spatial datasets representing various environmental scenarios. The GIS-based multi-criteria decision making approach is so simple and flexible that any number of criteria and indicators can be employed (Phua and Minowa, 2005). The application of multi-criteria analysis is so wide that it can be applied for different purposes as a base of decision making process and policy formulation. As pointed out by Malczewski (2006) there are two fundamental classes of multi criteria evaluation methods in GIS: the Boolean overlay operations (non-compensatory combination rules) and the weighted linear combination (WLC) methods (compensatory combination rules). In this case the application of multi criteria analysis for this study is more depending on Boolean method. Moreover, the
effectiveness of GIS analysis in this sense is highly dependent on the quality of the input datasets and consistency of the spatial reference system for each dataset so that they confirm each other accurately.

From the study carried out based on time series land use change on the plant’s coverage area, expansion of agricultural parcels and urbanization are found to be the most determinant factors for the continuous extinction of *G. pilosa*. An extensive human activity in the general study area is causing multiplying effect on the plant coverage area. The increasing economic activities are basically pushing the natural landscape and affecting the growth and survival of small plant species like *G. pilosa*. GIS based change detection analysis allows identifying environmental pushing factors that force a particular feature to lose its original geographical extent. Habitat quality variables (Honnay, Hermy & Coppin, 1999) play an important role in the colonization process of plant species. Planning and environmental protection policies and actions in relation to urbanization process have to consider the existence and survival of small plant species also. If the trend continues, the plant would be in risk of total extinction and then would result in affecting the biodiversity of the area as a large. From the result of this study, further research is suggested to be carried out on the two way relationship between the dwarf plant species *G. pilosa* and other larger vegetation types since inconsistent result were found with respect to their relationship.
References


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Zhang, X., Kang, T., Wang, H., & Sun, Y. (2010). Analysis on spatial structure of land use change based on remote sensing and geographical information system. International Journal...

Appendix 1

Path 195 020 Landsat imagery.

Path 195 021 Landsat imagery.
Layer stacking of seven bands for Path 195 020 Landsat imagery.

Layer stacking of seven bands for Path 195 021 Landsat imagery.
Appendix 3

A) Successive imageries on mosaic tool window

B) Cut line for mosaicking the imageries.
C) Mosaicking of path 195 020 and 195 021 imageries.
Appendix 4

*G. pilosa* growing on sandy soil hilly areas with in wetland area; picture taken from a hilly area on the field study.