Landscape Modelling with Geographical Information System (GIS): a field application in Peru

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1. Introduction

Landscape evaluation and analyst is the process that provides a consistent platform for spatial information for industry planning and application. Also, it can serve as a model to strategic investment in the region as bring engagement and commitment to investors. Likewise, it integrates several disciplines and improves decision making. Moreover, the patterns or results detected can be used to assess the impacts of past or future disturbance (natural or human) and to plan and regulate further human use.

The purpose of this field case was to perform a landscape evaluation, using Geographical Information System (GIS) analysis and applying it to natural landscapes in the study area, a site where several physical and anthropogenic activities have been found to take place.

The main objective was to describe the study area's Landscape Visual Quality (LVQ) through modeling of landscape scenarios using GIS spatial analysis tools.

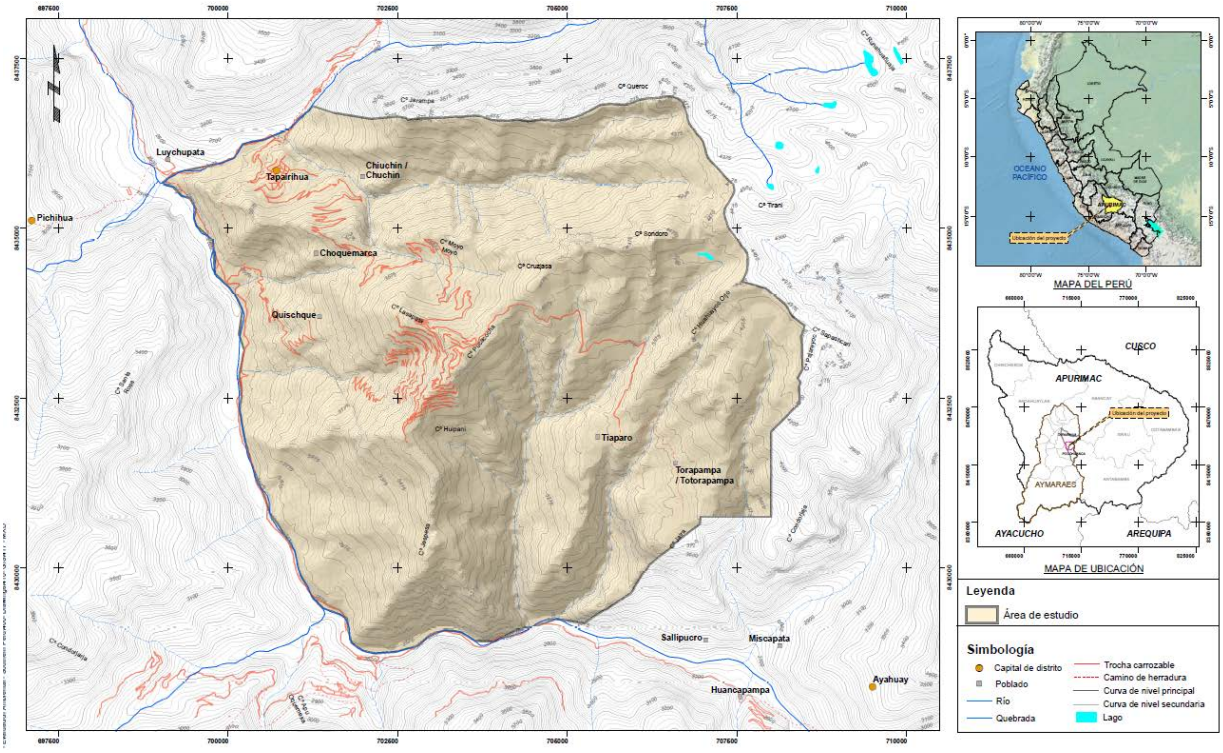
The scope of this study includes:

- The evaluation of seven landscape "criteria": morphology, vegetation, water, color, rarity, scenic background and human performance. Evaluation was based on assessing factors such as topography, physiographic units, local hydrology, vegetation units, protected natural areas, archeological findings, and the presence of population areas and the operations facilities.
- The evaluation of the Landscape Visual Quality (LVQ) based on a geographic information system (GIS) model.
- The validation of the model through the location and description of Field Observation Points (FOP) in the study area.

2. Study area

To determine the Study Area for the landscape analysis, the specialist considered geographical, biological, social, and future impact factors (e.g. operation location during the exploration mining phase). Geographically the study it's centrally located by longitude 73.10 ° W and latitude 14.16° S. Administratively, is located in the Tapairihua and Poccohuanca districts, Aymaraes province in the Apurimac department (southern Peru). See Figure 1.

Figure 1



Elaborated by the author, 2012

3. Methodology

Quality analysis for Visual Landscape Evaluation (VLE) involves assessing seven criteria: morphology, vegetation, color, water, scenic background, rarity and human performance. Assessment data were contrasted with field observation data.

For the LVQ analysis in the study area, geographic information systems (GIS) were used. The sources of information used in this analysis have been developed as part of the independent studies, as follow:

- Physiography,
- Slopes,
- Vegetation units,
- Local hydrology,
- Archaeological sites,
- Nearby communities
- Mine location and facilities.

This study was conducted at a scale 1:45,000.

4. Evaluation of the Landscape Visual Quality (LVQ)

The assessment of the current characteristics of the landscape was based on LVQ, which is a methodology that is part of the Visual Resource Management (VRM) model proposed by the U.S. Bureau of Land Management (2010 and 2011). It is a method that has been designed to protect the visual landscape value and reduce the effects of various activities on this value. The methodology has been adapted, according to the proposal by Uzun and Muderrisoglu (2011), to be used at regional and subregional levels (at a scale of 1:50,000). It has also been used effectively on a smaller scale in other studies (Bureau of Land Management, 2010; VRM Africa, 2008).

5. Field Observation Points (FOP)

During the assessment of LVQ (Table 1), field observation points (FOP) were located on the principal access, rural roads and in areas of wide accessibility to the observer.

6. Evaluation Factors

The method is based on the assessment of seven basic visual features of the landscape: morphology, vegetation, water, color, scenic background, rarity and human performance. Each feature will be scored according to specific evaluation criteria.

Table 1 Evaluation criteria for each of the LVQ factors

Factor	Valuation criteria	Score
Morphology	Very mountainous, marked and prominent relief (with cliffs, spires and large rocky formations); wide variety of surfaces or much eroded.	5
	Erosive forms, sizes and/or shapes with/without varied relief. Presence of interesting shapes and details but nothing dominant or exceptional.	3
	Soft hills, flat valley bottoms, few or any unique details.	1
Vegetation	Great variety of vegetation types with interesting shapes, textures and distribution.	5
	Some variety in vegetation but only one or two types.	3
	Any variety or contrast in vegetation.	1
Water	Dominant factor in the landscape; clean and clear. Presence of rapids and waterfalls.	5
	Flow water or backwater, but not dominant in the landscape.	3
	Absence or presence.	0
Color	Combinations of intense and varied color or pleasing contrasts between soil, vegetation, rock and water. (from the field specialist point of view)	5
	Some variety and intensity of color and contrasts between soil, rock, vegetation.	3

Factor	Valuation criteria	Score
	Rarely any variation in colors or contrasts.	1
Scenic background	The surrounding landscape greatly enhances the visual quality.	5
	The surrounding landscape moderately increases the visual quality of the whole.	3
	The surrounding landscape has no influence on the visual quality of the whole.	0
Rareness	Unique or very rare in the region.	5
	The landscape is characteristic.	3
	The landscape is common in the region.	1
Human intervention	Human actions or modifications which can affect negatively the visual quality.	2
	The scenic quality is slightly- or unaffected by disharmonious modifications.	0
	Intense and extensive modifications that reduce or nullify the scenic quality.	–4

Source: BLM, 2010.

The total sum of these factors determines the landscape's visual quality classification, according to the following Table:

Table 2 LVQ classification

Class	Description	Score range
III	Areas of high quality with unique and outstanding features.	19-33
II	Areas of average quality, whose characteristics have variety in form, color and line, but seem common in the study region and are not exceptional.	12-18
I	Areas of low quality, with little variety in shape, color, line and texture.	0-11

Source: BLM, 2010.

7. LVQ Spatial Model

The LVQ model involved spatial analysis and 3D analysis, which were used to merge, model and unite the seven factors or layers contrast with the FOP.

8. Results

Field Points of Observation (FOP)

In the study area 19 points of observation (PO) were settled for landscape analysis. Table 3 shows the summary of the PO and landscape classes in the study area with their LVQ scores.

Table 3 Points of observation and landscape classes

PO	Coordinates UTM18 South		LVQ Scores
	east	north	(class)
PO-01	701 322	8 433 639	9.47 (I)
PO-02	702 922	8 433 594	11.58 (II)
PO-03	703 647	8 433 292	15.37 (II)
PO-04	704 075	8 434 336	19.75 (III)
PO-05	704 591	8 434 458	14.78 (II)
PO-06	704 730	8 434 339	17.88 (II)
PO-07	705 117	8 434 540	17.75 (II)
PO-08	705 490	8 434 732	16.86 (II)
PO-09	705 848	8 434 954	17.14 (II)
PO-10	706 876	8 434 104	17.56 (II)
PO-11	705 623	8 433 531	21.22 (III)
PO-12	707 414	8 432 295	15.44 (II)
PO-13	707 064	8 432 470	16.59 (II)
PO-14	705 844	8 432 892	5.75 (I)
PO-15	701 544	8 434 303	22.59 (III)
PO-16	701 571	8 432 848	30.23 (III)
PO-17	705 242	8431 849	8.55 (I)
PO-18	704 042	8 431 708	31.58 (III)
PO-19	702 888	8 434 398	32.28 (III)

Source: Elaborated by the author, 2012

Figure 2 shows the location of the FOP and the description and evaluation of the LVQ at each of these points.

LVQ assessment factors

Each one of the seven criteria was independently evaluated using analysis of GIS data and ArcGIS software. The following are the findings for each evaluation factor.

- **Morphology**

Morphology was evaluated according to the existing physiographic units in the study area. Areas with a relief of wavy features, and steep and stony slopes had higher LVQ scores, while those middle riddle areas with mild to moderate slopes and rocky terrain had slightly lower LVQ.

- **Vegetation**

Vegetation was evaluated according to the existing vegetation units in the study area. Those natural vegetation units have unique features, greater diversity of species and lower distribution in parts with higher LVQ scores. Areas dominated by open spaces with little or no vegetation had lower values.

- **Water**

The water factor was evaluated according to the hydrology of the study area. Water bodies present in the right bank of the Antabamba River, within the Alto river basin (in Apurimac), were considered. Also, water bodies framed within the interbasin in Alto Apurimac (which is part of the Ucayali river basin) were also considered.

- **Color**

Color factor is a critical component of the landscape, and it was evaluated according to the vegetation units present in the study area. The variability of the color range was also taken into account. As for the color evaluation, natural vegetation units were found to have the greatest variety, contrast and harmony. Thus they were also associated with a high LVQ. In contrast natural vegetation units with limited variety were associated with a low LVQ.

- **Scenic Background**

No scenic background was found in the study area or surrounding landscape. Thus the LVQ is considered low.

- **Rarity**

The rarity factor is an essential component of the landscape and it was evaluated according to the importance and uniqueness of the area being studied. Protected areas and national parks generally have the highest values of rarity, but these sites do not appear within the study area. For this evaluation, the Evergreen Forest and cliff units were considered as they contained greater biodiversity; thus they were found to have a high LVQ. The scrub vegetation associations are not considered rare. But because they play an important role in ecosystem functionality, they were found to have a medium LVQ. The areas that do not show any degree of rarity or do not contribute positively or negatively to the criteria and were found to have a low LVQ.

- **Human performance**

Due to changes in the landscape the human performance factor is the only factor where negative scores were obtained. All areas occupied by the project had a low LVQ. The only anthropogenic components that could contribute positively are the archaeological sites. Other areas (towns, agricultural land, etc.) have no positive or negative influence on the LVQ.

9. Conclusions

The LVQ of the study area has been obtained by combining the scores for each of the evaluation factors. In Figure 2 three LVQ classes can be distinguished by considering the landscape modelling and the evaluated PO as control field points.

The study area is dominated by landscapes with high LVQ Class II (see Table 4). These landscapes are characterized by medium quality areas whose features have variety in form, color and line; but they are common in the study region and are not exceptional. These areas studied were found to have a wide variety of vegetation units and a high visual contrast.

Table 4 Landscapes classes distribution

Landscape visual quality	Area	
	Hectares	%
Class I (low impact)	598.08	10.94
Class II (moderate impact)	3105.96	56.80
Class III (high impact)	1764.60	32.26
Total	5468.64	100.00

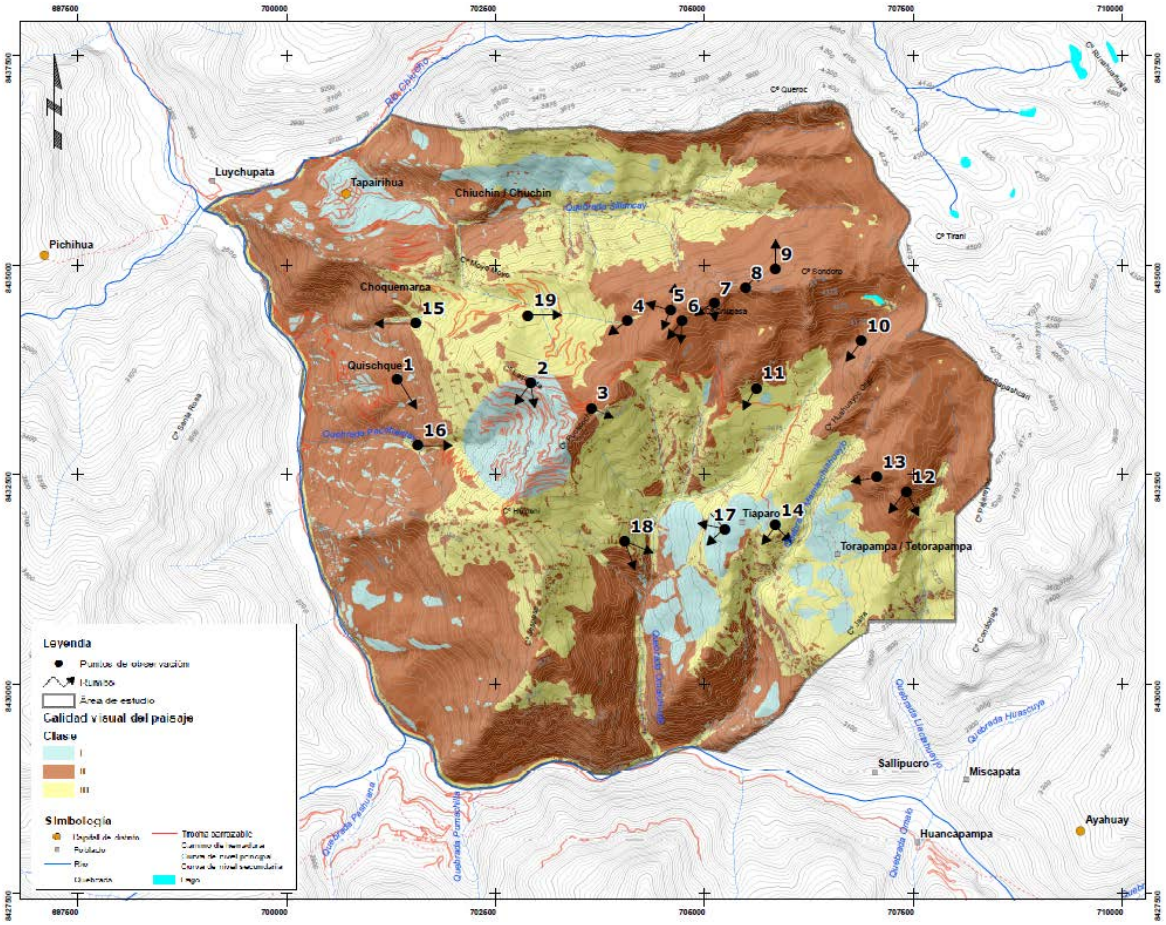
Source: Elaborated by the author, 2012

The landscapes with high LVQ (Class II) are distributed as patches and occupy the highest percentage (56.80%) within the study area. They are generally located on rolling hills and steep slopes, and they are characterized by a diverse and colorful vegetation, the presence of water, and the absence of human performance. The landscape with a medium LVQ (Class III) occupies 32.26% within the study area. They are distributed in the rolling peaks and slopes and are moderately steep; they have natural vegetation and some features of contrast without significant human performance. The landscapes with low average LVQ (Class I) occupy 10.94% within study area. They are distributed on lower slopes and areas with wavy altitudinal elevation, which are the locations of the predominant population centers and grounds for agriculture.

The landscapes with low LVQ (occupying 10.94% of the study area) were found to correspond to areas where the morphology, vegetation and color have been modified by human performance. See figure 2

Figure 2

LVQ Results and FOP



Source: Elaborated by the author, 2012