

Landscapes of Andenes and Sustainable Infrastructure in Andean Cities

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Abstract

This article aims to analyze cities located in the high mountain ecosystems formed by the landscape of Andenes or sustainable infrastructure of terraces located in the Ecuadorian and Peruvian Andean highlands of central South America. The selected case studies have in common the use of land for settlement purposes, and the fact that they pursue both urban and rural infrastructure sustainability approaches. Theoretical and empirical methods were used such as the historical-logical method, the inductive-deductive method, observation *in situ* and reviews of documents and maps. It is concluded that the anthropic interventions and the management and monitoring plans of each site allow for the conservation of their natural resources and of the landscape of Andenes, the improvement of the population's quality of life, the control of structural risk to prevent erosion of the mountains where they are constructed as well as the preservation of the site's globally significant cultural heritage (as recognised by UNESCO). Current trends in the sustainable use of cultural and natural resources of the heritage involve the conservation of terraced landscapes. Without their preservation, management or exploitation as a tourist resource cannot be carried out.

Keywords

Andean Highlands, Andenes, Sustainable Landscape, Cities, Infrastructure, Heritage

1. Introduction

The architecture of Andean landscape is linked to nature, culture and the ways of life and subsistence of past and present societies, These facts, as well as their value for research, have led to their being considered as a site of world heritage, as declared by UNESCO.

Natural aspects of the landscape such as the geology, geomorphology, aptitude and edaphic quality of the soil, climate, biodiversity, surface and underground water resources, climate, seismicity and the likelihood of risks, determine to a large extent the various land uses to which they are subjected by human activities.

The use of the land also requires consideration of the physical forms that allow the development of these activities, specifically agricultural and residential activities. It is necessary to apply geomorphology as a scientific discipline to the landscape of the Andenes (also known as the landscape of terraces) in order to understand the processes of the modification of the terrain relief. It is also necessary to consider their topography, soil drainage, soil texture, natural vegetation and the functional use of the soil for economic exploitation by society.

Of the components of the natural environment, topography represents the most important aspect of the configuration of the landscape. This case study on the Central Andes Mountains is based on that premise. In this study it is appreciated that landscape design must conform to the characteristics of the natural environment and the relief of slopes in order to obtain a high standing from the point of view of the shape and function of the modified land.

The landscape of Andenes is determined by the geomorphology and altitude of relief that precipitation. In addition to this, natural hazards such as earthquakes, landslides, volcanism, floods, and hurricanes are factors to consider in the sustainable landscape of the Andenes.

According to Careri (2013), the first transformation of the landscape was not a physical construction but rather a symbolic construction of the terrain, realised through walking [1]. In this primitive fact lies the root of the relationship between architecture and travel, as the multidirectional space of natural chaos started to become an orderly space.

Norberg-Schulz proposes that the character of the place is, in the main, a function of topography and suggests that the description of the place transcends geography and adheres to the field of culture and the landscape [2].

The International Terraced Landscapes Alliance (ITLA) [3] developed a manifesto that raised concerns about the abandonment and degradation processes of terraced landscapes. Since then, ITLA has been promoted to recover and sustainably manage terrace systems. This involves the prevention of soil erosion, mitigation of the effects of climate change flood control and management of water systems; protection and improvement of agrobiodiversity and ecosystems; diversification of the rural economy to increase the value of food, seeds and crops; the willingness to choose these areas as a viable way of life; understanding the educational value of heritage cultural landscapes, and the personal and natural histories of those who are embedded there; and promoting the beauty and attractiveness of these landscapes for leisure and tourism.

2. The Sustainable Infrastructure of Andenes

The Andes Mountains occupy the western part of South America, forming part

of the territories of Argentina, Chile, Bolivia, Peru, Ecuador, Colombia and Venezuela. Mora *et al.* (2010) [4] studied their geography and geomorphology. Their average height range from 2800 to 4000 meters above sea level and they are ecosystems that contain the highest volcanoes on the planet. Seismic movements and subsequent volcanic activity have been more important in the configuration of the relief than external erosive agents. The current morphology contains high mountain ranges, along with extensive high plateaus and deep longitudinal valleys running parallel to the great mountain ranges.

Different sources ([5] [6]) state that the word Andes comes from the word “anti” in the Quechua language, meaning east, or the cardinal point where the sun rises. Spanish etymology, states that Andes comes from the word “andén”; however, it is likely that the Spaniards modified the Quechuan word anti upon noticing that there were many crops grown on the andenes of the slopes of this mountain range.

The andenes, a product of the Inca culture, were one of the largest and most important infrastructure and landscape adaptation works in Pre-Columbian America. Over thousands of years, before the conquest and colonization of the American continent, the Andean culture perfected the construction of the system of terraces or andenes not only for the agricultural production of corn, but also for the management of water and for its architecture.

Hyssop (1990) [7] states that since the Inca period of the so-called “Children of the Sun”, many valleys of the Central Andes had a system of terraces for the cultivation of corn and other fruits, with an irrigation system from the springs and streams of the main rivers, at an altitude of 3750 metres. The Incas synthesised the environment and its construction, not only to accommodate the natural characteristics of the land, but also to modify the landscape.

Hyssop (1990) [7] adds that the influence of the Inca Empire extended beyond Peru, and reached territories in present-day: Ecuador, Colombia, Bolivia, Chile, and Argentina between the fifteenth and mid-sixteenth centuries. The andenes in the Andes are an example of anthropogenic landscape processes that contributed to food security and the development of pre-Hispanic Andean civilizations. They allowed the Incas to manage climatic and geological risks, and extend the agricultural frontier to include sectors with irrigation, water storage and access works.

Zuidema (1964) [8] and subsequently Kendall and Rodríguez (2009) studied the design of a sloping wall in the Inca Imperial architectural style, which was an ideal solution for the support of the andenes on stepped slopes. This culture attached great importance to the details of its constructions, mainly in the sacred sites or *ceques* that started from an alignment on andenes from the center of Cuzco in Peru, to the four *suyus* (large geopolitical units of the Inca Empire) that involved ditches cared for by social groups called *avilas*.

Bauer (2000) [9], and Kendall and Rodríguez (2009) [10] investigated the design of the irrigation canals and the andenes of the Incas which have lasted 500 years with few subsequent modifications. It was found that this is due to the de-

sign, which is highly integrated in the details of its construction. Additionally, the hydraulic works and terraces show an evolution in these agricultural infrastructures and human settlements.

Other authors such as De La Torre and Burga (1986) [11] explained that in the 15th century, the Incas invested resources in landfills and stone walls to control the erosion of the mountains where they built their ceremonial centers. For example, any of the andenes on the west end of Machu Pichu were built for that purpose. After the Spanish conquest, the use of the andenes was maintained and to this day there are regions where they are cultivated abundantly. Since 1980, efforts have been made toward the rehabilitation of terraces to recover the use of environmental and cultural infrastructure and to contribute to increasing the agricultural production of low-income communities, predominantly in the south of the Peruvian Andes thus contributing to rural development [11].

Between the center of Peru and the north of Bolivia there are some very well-preserved sets of andenes. In the citadel or human settlement of Machu Pichu in Peru, the terraces were used as structural support elements and as a drainage system, which was necessary because of the large amount of rainfall in that area of jungle. The introduction of andenes in the design of the villages is influenced by aspects of the Inca religion that involves complex rites based on the growth cycle of several crops, in which corn was particularly important [11].

In the area of Cuzco founded by the Manco Cápac, the highly prestigious andenes of human settlements can be found in places such as Tipón, Yucay, Ollantaytambo, Pisac Chnchero, in connection with towns that could be considered the finest examples of Inca architecture, built by the Incas as rural residences [9].

The Incas developed the art of stone carving and building andenes to the point where it ceased to have a merely utilitarian value. They combined an aesthetic appearance with a demonstration of imperial power. The Temple of the Sun, or Coricancha, was one of the most important temples in the Inca capital. It was an imposing piece of architecture since it was lined in gold and silver, and was dedicated to the cults of the gods. The andenes of the Sacred Valley of the Incas in Cuzco draw particular attention to the assemblies of the concentric andenes of Moray, and the huge terraces of Pisaq and Ollanta [9].

In 2003, a regional project related to community cultural tourism on the Inca Trail (or Qhapaq Ñan) of the Andean highlands was initiated by the governments of Bolivia, Peru and Ecuador. The intention, was to implement an economic alternative and to enhance the towns that are within the routes of the ancestral road system, through the provision of tourist services for the travelers that visit the region. This Andean road system was added to the UNESCO World Heritage List in 2001. Colonial religious structures are one of the indicators for the identification of Inca roads because many of them were built on Spanish religious structures from the colonial era linked to Inca settlements [12].

Casaverde (2003) [13], and Avilés (2008) [14] declared that during the Inca rule, the constructions and the royal Inca road known as Qhapaq Ñan were carried out according to an administrative control policy. During the Spanish con-

quest of America in the 16th century, the Spaniards took possession of Inca constructions and, built on them. They moved within the axis of the road network or simply built outside the Inca road system in connection with the opening of new Hispanic centers of colonial production from 1645 many churches were built in the city of Cuzco, in addition to schools such as San Bernardo and San Francisco de Borja [15]. After the earthquake that hit southern Peru in 1650, colonial cities were rebuilt with architectural codes inspired by the Spanish Renaissance and later the Baroque school [15].

3. The Heritage Andenes of the Historic Center of Quito, Ecuador

Father Juan de Velasco recounts in one of his legends that before Spanish colonisation, there were two temples in the primitive city Quito-Cara: the first, dedicated to the sun and located at the top of the Panecillo hill (an example of the bohío type, which has a rectangular base with a pyramidal top) and the second, belonging to the moon and stars, on the Huancauri hill (currently San Juan) and inscribed within a circular base (Neira, 2018) [2].

The quitus were originally from the Pichincha area, in Ecuador. According to Father Juan de Velasco (cited by Neira, 2018) [2], two dynasties ruled the Kingdom of Quito until the Inca conquest in 1487. The legendary Inca emperor Atahualpa was the last living quitu. Its birth has not been verified but speculation is that it was in Caranqui or Quito.

Gómez Jurado (2016) [16] states that the invasion and subsequent Inca occupation of Quito and its surrounding sectors occurred from the mid-fifteenth century until 1534, the year in which the Spaniards arrived. Father Juan de Velasco mentions in one of his writings that the Quito-Cara temple of Yavirac was rebuilt by Huayna Cápac. Its columns remained intact until the arrival of the Spaniards, who dismantled the temple in search of treasure. The residence of the Inca, their court and some buildings to house the army were also located in the Yavirac (Gómez Jurado, 2016) [16].

The rugged terrain of Quito sits at an altitude of 2850 meters above sea level and is located in the valley of Guayllabamba, near the Pichincha volcano. During the dominion of the Incas in Ecuador, the lodgings were built with embankments and retaining walls that mimicked the topography in the form of bleachers (Neira, 2018) [2]. The Panecillo hill was one of the four reference points that divided the Inca city (Huancauri to the north; Itchimbia to the east; Cayminga to the west and Yavirac to the south). From this, theories have emerged about the spatial quadripartition or “Tahuantin” of the city of Quito (Neira, 2018) [2].

From 1534, the town of San Francisco de Quito was established, designed in the form of a grid or checkerboard starting from a main square, a feature that remains today. Constructions included any churches and chapels, convents and monasteries, squares, museums and various homes. The style of the homes was a sober, austere unornamented Colonial style, with wide adobe walls, central courtyards with galleries, orchards and stone floors.

The colonial houses were built on the hills and extended down from the terraces until they reached the street. At the entrance they have hallways with stairs, which connect the street to the central courtyard of the house. Gómez Jurado (2016) [16] states that at the beginning of the 19th century, Quito had 25,000 inhabitants and extended across a 13 × 13 block grid. Quito did not have purpose-built recreational spaces, therefore the Alameda Park and the Panecillo Hill acquired this character.

In 1978, the historic center of Quito was declared a Cultural Heritage of Humanity by UNESCO. It is an important example of the adaptation of urban landscape to topography and abrupt geomorphology.

The centre of Quito has a concentric radial organisation: from the square the city grows out towards its surroundings. It is a large colonial town comprising 16 neighborhoods, including the central nucleus and the eastern peripheries. It occupies more than 370 hectares and has a very valuable and well-preserved catalogue of heritage infrastructure. At present it incorporates both residential use and cultural tourism use due to its impressive artistic and religious heritage in an optimal state of conservation.

4. Abandonment of the Sustainable Architecture on Andenes Infrastructure in the Historic Center of Quito

During the twentieth century the historic centre of Quito suffered from an abandonment of the practice of primitive architecture of andenes. This is probably due to the high cost of forming andenes and the development of urbanized land. Housing began to be built on steep slopes with an obvious risk of landslides, a situation that continues to this day.

The Panecillo or Yavirac as the pre-Inca indigenous population knew it, is approximately 300 meters above sea level and marks the old southern limit of the city (Neira, 2018) [2]. Access to this neighborhood is determined by an ancient spiral-shaped path that crosses the neighborhood and culminates in the statue of the Virgin of Quito. Additionally, in the Yavirac there were settlements of the Quitu-Cara culture. **Table 1** summarises the main characteristics in the settlement of El Panecillo.

Table 1. Main characteristics of the cultural and natural heritage and the structural risk in the settlement of El Panecillo.

Characteristics of the site	Cultural and Natural Heritage	Structural Risks
El Panecillo settlement in the Historic Center of Quito	<ul style="list-style-type: none"> • The neighborhood has a very large historical and cultural component. • The mound served as a natural astronomical observatory due to its geographical location, relative accessibility and altitude. • Buildings deterioration in environmental conditions due to the abandonment of green areas and public spaces. • According to the newspaper The Telegraph despite the reputation that the neighborhood has among the general population of Quito as being unsafe, its inhabitants comment that the sector is quiet and has been safer for about four years. 	<ul style="list-style-type: none"> • Spontaneous and progressive urbanisation process that denotes disorder and precariousness. • The quality of the building and equipment is rather modest compared to surrounding sectors. • The form of construction of the houses is usually on the factory line and on two floors. The use of adobe, wood and tile predominates. • The municipal authorities implemented reforms such as the relocation of street sellers, the improvement of signalling, the establishment of greater police control, and the improvement of gardens.

There is a spontaneous and progressive urbanisation process that denotes disorder and precariousness in its buildings and deterioration in environmental conditions due to the abandonment of green areas and public spaces. The form of construction of the houses is usually on the factory line and on two floors. The use of adobe, wood and tile predominates. The quality of the building and equipment is rather modest, compared to surrounding sectors (Gavilanes, 2019) [17].

At present, it has been proposed by the municipal authorities of the historic center of Quito, to declare the Panecillo hill a tourist site. This involves environmental reforms such as the relocation of street sellers, the improvement of road signs, the implementation of greater police control, and the improvement of andenes infrastructure, gardens and green areas. These measures can raise the visual quality of the landscape, however there is no plan for the neighborhood to rehabilitate the andenes architecture that the old city possessed.

5. Outcomes and Discussion

Sustainability in scientific research is highlighted by the connection of works with the solution of existing problems, in the environmental and sustainability issues of some communities and social groups (Ruiz, 2016) [18].

The theoretical definitions and concepts regarding the sustainable landscape of andenes from researchers [1] [2] [19] and from international organizations such as UNESCO and IITLA, appreciate the complexity of the existing interrelationships of the andenes with the heritage, the land and their use for sustainable tourism that can contribute to its conservation.

It is observed that the use of andenes for sustainable tourism in the heritage landscape of the high Andean mountains is appropriate. This is because the initial concepts that lead to its declaration by UNESCO as a World Heritage Site have been maintained.

The criteria recognised in the two cases studies that focused on the sustainable landscape of andenes derived from the heritage of the Inca culture and of the historic centre of Quito, have been fulfilled in the UNESCO world heritage declarations. They are evaluated in **Table 2** below.

The legal, economic and regulatory tools are not effective on their own in order to create awareness and attitude about the need for the protection and care of the environment, if they are not accompanied by a strong environmental culture that preserves nature and the cultural identity of the towns. Education and environmental disclosure need to be reinforced encompassing all the bodies, institutions and the community. It is imperative to develop programs for improvement and training of those who make decisions, technicians and workers in general (Ruiz, 2016) [20].

The cultural heritage management plans are intended to preserve and protect the cultural heritage from the adverse impacts related to the construction and operation of any of the components of an infrastructure or tourism project in each of the places within the territory that have historical cultural value.

Table 2. Criteria recognized in the UNESCO world heritage declarations.

World Heritage criteria	Inca andenes in the Andes Mountains	Andenes in the historic centre of Quito
1) To represent a masterpiece of human creative genius.	1	1
2) To exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design.	1	1
3) To bear unique or at least exceptional testimony to a cultural tradition or to a civilization that is living or has disappeared.	1	1
4) To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history.	1	1
5) To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change.	1	1
6) To be directly or tangibly associated with events of living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance.	1	1
All criteria fulfilled	6	6

6. Conclusions

1) The settlements of the Andes Mountains all emphasize: the preservation of heritage *in situ* as the best way to protect cultural heritage; the importance of obtaining environmental permits and licenses; the importance of establishing procedures for the monitoring, evaluation and treatment of archaeological assets and casual findings, and the training and awareness of workers and residents regarding conservation and their responsibilities regarding cultural heritage.

2) The implementation of management plans and intelligent monitoring within an integrated territorial planning is required. In this regard, the case studies of the high Andean mountains of Peru and Ecuador are a paradigm of how sustainable tourism should be implemented in other sustainable landscapes of Andenes in an advanced state of degradation in seismic areas.

3) In the experiences of the Andean mountains, it has been possible to contemplate the integration of the terraced landscape with the urban area. In addition, environmental management for sustainable tourism purposes has proven to be a source of income to the areas. The integration of the population in the management plans as active and fundamental entities in their implementation has contributed to heritage conservation and to projects that will benefit the landscape environment.

4) In Andean cities conservation of monuments with appropriate tourist management, the legacy of the heritage from the Inca culture and the sustainable

architecture of Andenes is by various institutions. Of these, the work of the University of Cuzco in Peru in coordination with prestigious international institutions such as UNESCO stands out.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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