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Author: Byers, Alton C.

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Alton C. Byers

Contemporary Landscape Change in the Huascarán National Park and Buffer Zone, Cordillera Blanca, Peru

As part of The Mountain Institute's monitoring and evaluation program, historic landscape photographs from 10 photopoints of the 1936 and 1939 German/Austrian climbing and cartographic expeditions to the Cordillera Blanca (Huascarán National Park) were replicated in 1997 and 1998. Comparisons revealed contemporary changes in native forest cover, nonnative forest cover, glacial recession, grazing impacts, and urban expansion. Results indicated an apparent stability and/or increase in native Polylepis *forest cover, significant regional increases in nonnative* Eucalyptus *and* Pinus *forest cover, improved pasture conditions in some areas, widespread glacial recession, and increases in regional urbanization. Important management-related questions in need of further study are identified, such as the impacts of cattle on* Polylepis *regeneration, correlations between road construction and forest loss, long-term impacts of nonnative forests, and strategies for the reintroduction of native forest species. Increasing the photographic, quantitative, and oral databases for the Huascarán National Park and buffer zone will continue to provide important insights regarding contemporary landscape change processes, human versus natural impacts, and future management and restoration options.*

Keywords: *landscape change; natural resource management; Huascarán National Park; Peru; photo monitoring.*

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Introduction

Protected area managers in mountain environments are often faced with a lack of reliable information regarding contemporary landscape and land use change processes, patterns, and prospective causes. The expense, remoteness, and logistical challenges of conducting long-term research in mountains further exacerbates the problem.

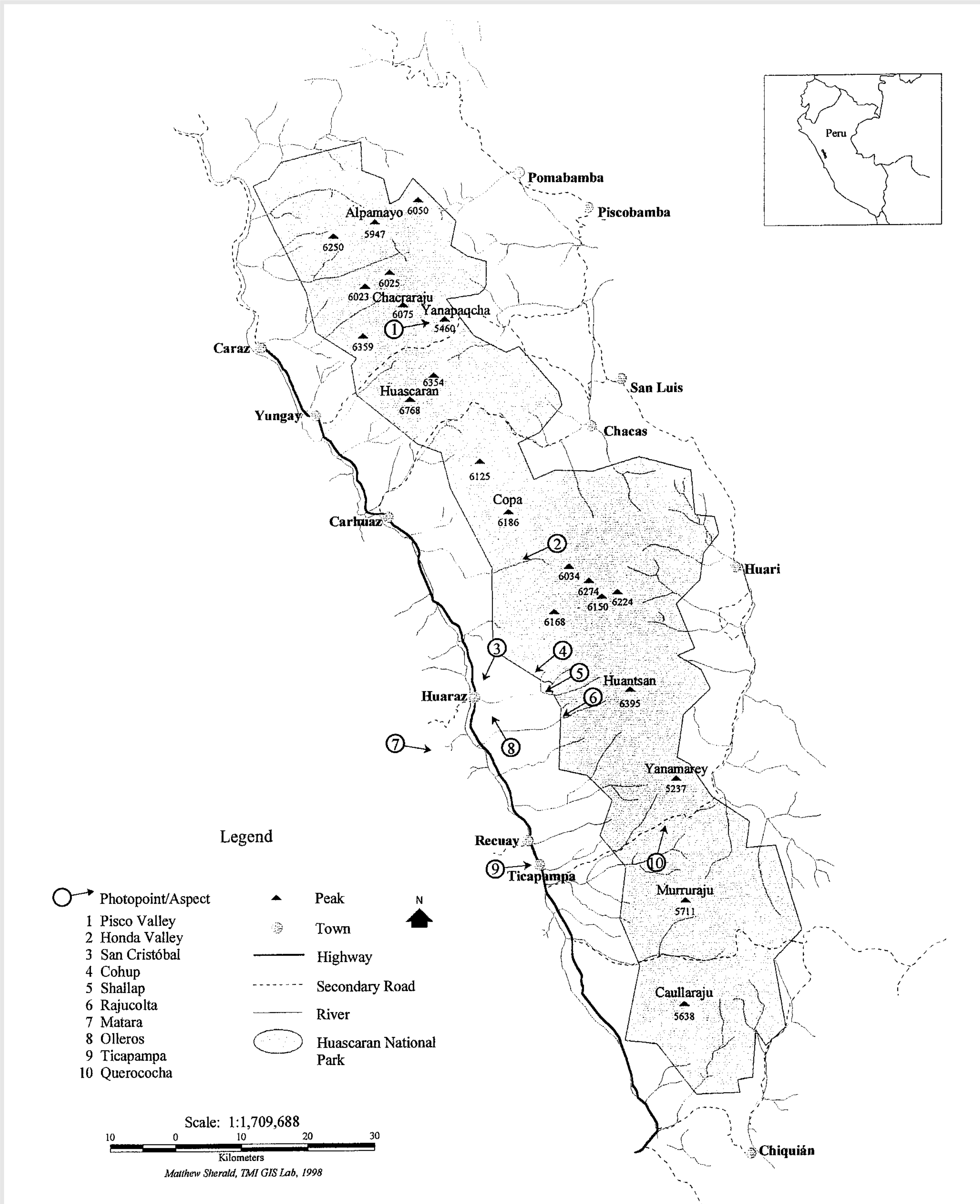
Repeat photography is an analytical tool capable of broadly and rapidly providing preliminary clarifications related to landscape/land use changes within a given region. As a research tool, it has experienced some utility in the United States during the past 30 years (Walker 1968; Heady and Zinke 1978; Gruell 1980; Rogers 1982; Vale 1982; Rogers et al 1984; Veblen and Lorenz 1986; Bahre 1991), to a lesser extent in the Nepal Himalaya (Byers 1987a,b, 1996, 1997a,b; Ives 1987; Fisher 1990:144–145), and rarely, with the exception of glacial recession studies (eg, Ames and Francou 1995; Ames 1998), in the Peruvian Andes (Byers and Kolff 1997). When supplemented by ground truth disturbance analyses, interviews with local people and scientists, and literature reviews, insights regarding resource management issues can be obtained within a relatively short period of time. Examples include clarifications concerning a region's historical and contemporary forest cover; changes in high altitude pasture conditions; glacial recession and formation of new glacial lakes; village growth or decline; impacts of catastrophic events, mining, and logging; and the effectiveness of management interventions over a prolonged period. Results, in the characteristic absence of a reliable data base, will often provide some of the first clarifications to the scientific and management communities regarding contemporary landscape change processes, human versus natural impacts, and future management and restoration options for a particular mountain setting.

Today, considerable uncertainty characterizes much of the understanding in the Peruvian Andes concerning the historical reduction of native *Polylepis* forests (Hensen 1991; Fjeldså and Kessler 1996; Oxford University 1996); the more recent introduction and spread of exotic *Eucalyptus* and *Pinus* sp; impacts of grazing, mining, and road construction within the park (Lozada 1991; Valencia, personal communication; Instituto de Montaña 1996); and the effectiveness of protected area and buffer zone management interventions (eg, afforestation, erosion control, and range/pasture projects). As demonstrated in previous studies in the Sagarmatha (Mt. Everest) National Park, Nepal (eg, Byers 1987b, 1997a), an integrated photographic analysis of landscape change processes in Peru contains the potential to provide clarifications. Following in the footsteps of Austrian geographer Hans Kinzl (1898–1979) and cartographer/mountaineer Erwin Schneider (1906–1987), this paper discusses the results of a preliminary investigation within the Huascarán National Park region, Cordillera Blanca, northwestern Peru, between 8–11 September 1997 and 1–15 July 1998.

The Huascarán National Park

The 3400 km^2 Huascarán National Park is in the Department of Ancash in north-central Peru and includes most of the Cordillera Blanca, the highest range of the Peruvian Andes and the highest within the world's tropical zone (Figure 1). The national park was established in 1975, declared a UNESCO Biosphere

FIGURE 1 Photopoint locations, Huascaran National Park and vicinity, Peru. Photopoints 1, 2, 3, 8, and 9 are illustrated and described in detail in this paper.



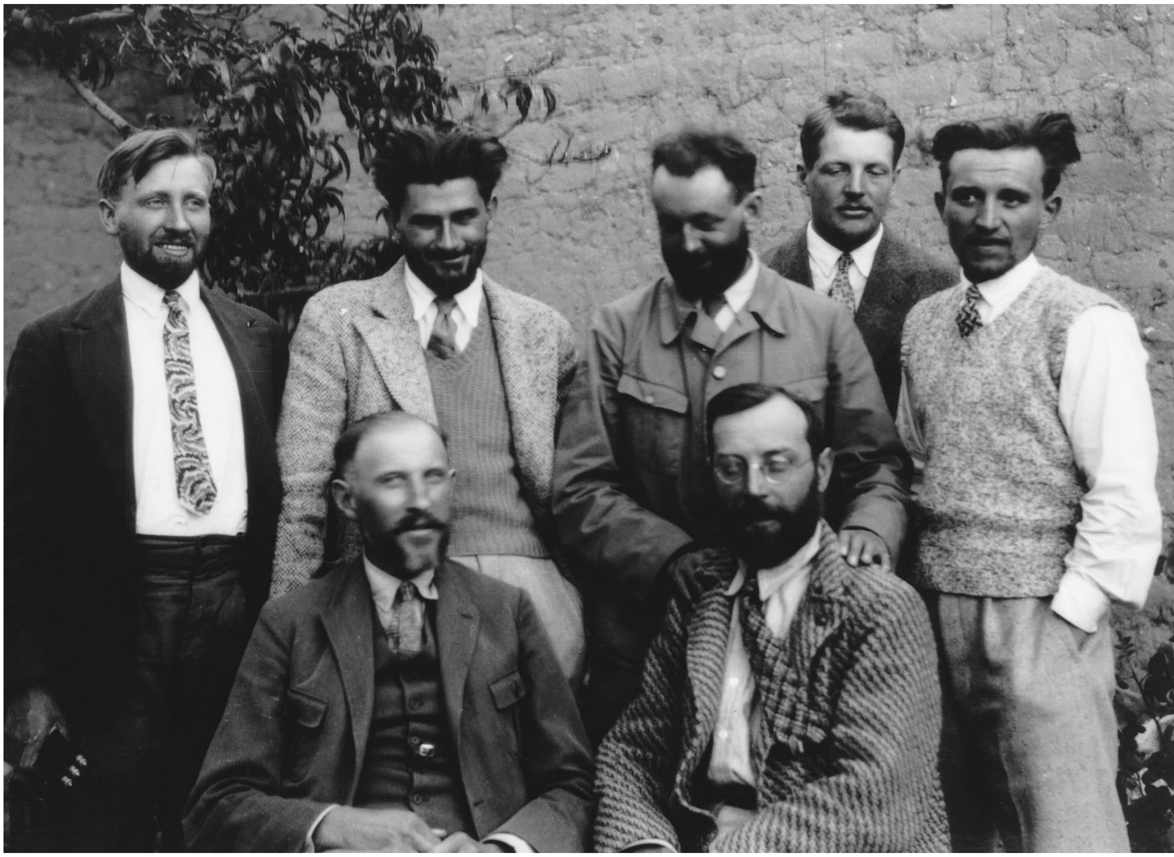


FIGURE 2 1932 German and Austrian Alpine Club expedition members. (Photo courtesy of Austrian Alpine Club Archives, Innsbruck, Austria)

Reserve in 1977, and a World Natural Heritage Site in 1985. The park contains 60 peaks with altitudes surpassing 5700 m, the highest being Huascarán at 6768 m. Forty-four deep glacial valleys transect the range from both west and east and, when combined with the extensive Peruvian mountain road system, provide relatively easy access for hikers, climbers, and the livestock of traditional cattle herders. Most of the terrain below 4800 m is characterized by high altitude grassland (*puna*) with remnant *quenual* (*Polylepis* sp) forests located within the upper, inner valley slopes. Although thought to have been greatly reduced during the past century (Fjeldså and Kessler 1996), the *Polylepis* forests contain a diversity of flora and fauna within the park while providing habitat for many species of endemic Andean birds. Approximately 779 plant, 112 bird, and 10 mammal species have been recorded for the region (Smith 1988; Brako and Zarucchi 1993; The Mountain Institute 1996; Kolff and Kolff 1997).

West of the park lies the agricultural valley of the Santa River, a densely populated region containing cities such as Huaraz (90,000 inhabitants), Caraz (15,000 inhabitants), and hundreds of rural villages. The cities are relatively modern and prosperous, although most of the people living on the slopes directly below the park continue to live under traditional Andean subsistence conditions. Quechua is generally spoken, with Spanish as a second language. The population of the 5710 km^2 buffer zone is approximately 226,500 (The Mountain Institute 1996), an estimated 10% of which directly use the national park's natural resources (eg, water, pastures, forests, the harvesting of medicinal and edible plants) (Walter 1994, unpublished manuscript, personal communication; The Mountain Institute 1996). The area east of the Cordillera consists of a group of valleys—headwaters of the Marañon River, a major tributary of the Amazon—known collectively as the Callejón de Conchucos. This area is much more isolated and less developed than the western slope region. Access is more difficult, and people are generally poorer.

Incomes are based primarily on agriculture and livestock. Tourism, particularly along the western slope, has grown substantially since the demise of *Sendero Luminoso* (Shining Path) guerrilla activity in the early 1990s, with more than 100,000 Peruvian and foreign tourists now visiting the park per year. The city of Huaraz serves as a tourism hub and a gateway to numerous trekking circuits, mountain climbing, and popular holiday and weekend destinations (eg, Llanganuco Lakes and the Pastoruri glacier/ski resort) (Bartle 1993).

Key environmental issues and challenges currently facing the region include the reduction of *Polylepis* sp forests, overgrazing of alpine and subalpine pastures, concentrated tourism, uncertain land titles and park boundaries, government policies supportive of resource extraction within the national park, and subsequent external pressures such as new roads, mining, dams, and tourist infrastructure. A park management plan was completed by the National Natural Resources Institute (INRENA) in 1990 and updated in October 1994. During 1995 and 1996, The Mountain Institute (TMI) worked with the government, nongovernmental organizations (NGOs), the private sector, and local communities to produce the Huascarán National Park Ecotourism Management Plan, the country's first participatory plan for a protected area (The Mountain Institute 1996). TMI is now in the process of implementing various components of the plan in conjunction with a series of integrated conservation and development projects (ICDP) for both the Cordillera Blanca and the more remote Cordillera Huayhuash to the south (Figure 1). The ICDPs are funded by the government of the Netherlands and the US Agency for International Development, including a monitoring and evaluation component, which includes this study.

The Photographic Record

In 1932, 1936, and 1939, three expeditions to the Cordilleras Blanca and Huayhuash were undertaken by the Deutscher und Österreichischer Alpenverein (DuÖAV, or German and Austrian Alpine Associations) with the objectives of high mountain exploration, research, and cartography (Borchers 1935; Kinzl 1940; Kinzl and Schneider 1950; Kinzl 1954; Kaser 1998:200; Kostka 1993:2). Under the direction of Austrian geographer Hans Kinzl (Penz 1997:5–8; see our Figure 2), climber/cartographer Erwin Schneider's triangulation and terrestrial photogrammetry from mid- to high-altitude photopoints throughout the Cordilleras Blanca and Huayhuash were used to produce the world-renowned Alpenvereinskarte maps (Kostka 1993; Kaser 1998:200), also generating thousands of glass negative plates (18 by 30 cm) in the process. Much of the data and photographic negatives from the 1939 expedition survive only because of the dedication of Professor Kinzl. Thousands of other superb Leica photographs also document the 1932–1940 climbing and research expeditions (Kaser, personal communication). Together, these older landscape photographs provide an unprecedented opportunity to qualitatively document contemporary changes in land use patterns, forest coverage, pasture conditions, glacial recession, the impact of catastrophic events, and other relevant features.

Methods

Ideally, older photographs should be replicated using the precise equipment and procedures employed by the original photographer (eg, camera type, lens, tripod height, film). Season, time of day, and weather conditions should also be replicated as closely as possible, which can be a challenging undertaking given the remoteness and high altitude of most photopoint stations. Seasonal attributes and weather conditions were nevertheless considered to be satisfactory for the present study. Budgetary and practical constraints prevented the use of the precise equipment used by the 1930 expeditions, such as the lightweight terrestrial phototheodolite (*Terrestrische Aufnahme Finsterwalder*, or TAF) developed by Professor Richard Finsterwalder in the 1930s for expedition fieldwork (Arnberger 1970:26–28). Nevertheless, the fundamental objective of the investigation—ie, high quality replication of the older, original photographs in order to assess large-scale landscape changes in the Cordillera Blanca—suggested that the equipment and techniques as outlined below would be adequate to obtain the desired results.

A Nikon F4S camera, 35-70 2.8 D zoom lens, and Bogen 3221 tripod with a 3026 ball joint head was used in combination with an MF23 Multi-Control Databack. The latter device was used because of its ability to perform automatic exposure bracketing, a feature of importance given the logistical, temporal, and financial demands of landscape change analyses in remote mountain settings. Additionally, black and white scenes were also replicated using Tiffen red, green, orange, and polarizing filters with the objective of maximizing the range of tonal values and characteristics available for the comparison and analysis process. Primary photographic replications were taken with 100 ASA black and white film, with Fuji 100 color slide film used for secondary color transparencies of the same scene.

Photopoint location was determined by cross-referencing the Alpenverein maps (Deutscher und Österreichischer Alpenverein 1988) for the Huascarán region (Cordillera Blanca, north and south: 1:100,000) with available 1932, 1936, and 1939 landscape photographs. The insights of local people interviewed were particularly important for rapid location of original photopoints as well as for an understanding of the factors of influence in apparent change; more detailed interviews are planned for the near future. Additional resources available to the project included the counsel of glaciologist Alcides Ames (Ames, personal communication), senior staff at ElectroPeru and Huascarán National Park, and photographs from pri-

FIGURE 3 Yanapaccha (5460 m) from Pisco basecamp region (Schneider, 1939)

FIGURE 4 Yanapaccha (5460 m) from Pisco basecamp region (Byers, 8 September 1997)

vate collections in Huaraz, the latter of which will ultimately permit further chronological analyses of landscape change phenomena for the years 1932, 1936, 1939, 1954, 1980, 1986, and 1994 (Ames, personal communication).

Results

Five of the 10 pairs of photographs obtained are illustrated and described in greater detail here.

Yanapaccha (5460 m) from Pisco basecamp region

Date: 8 September 1997
Time: 12:12 PM
Altitude: 4530 m
Aspect: 80°
Map photopoint number: 1
Original: 1939, plate box 9, number 2, 127, Schneider

In 1970, there were 722 glaciers covering an area of 723 km^2 in the Cordillera Blanca, the most extensively glacier-covered mountain range in the tropics (Ames et al. 1989). Significant glacial recession is believed to have commenced in 1862 (Ames, personal communication, citing Broggi 1943), with losses ranging between 552 m and 1910 m reported for individual glaciers monitored since 1932 (eg, Kinzl 1969; Pettersen 1967; Wilson et al 1967, cited in table II of Ames 1998). A significant body of scientific literature regarding contemporary (1930 to present) glacial recession in the Cordillera has been completed (eg, Pettersen 1967, Kaser, Ames, and Zamora 1990; Ames and Francou 1995:62–63; Hastenrath and Ames 1995a,b; Kaser 1995; Ames and Hastenrath 1996; Hastenrath 1996; Kaser et al 1996; Kaser and Georges 1997; Ames 1998, personal communication). Scientific and local concerns related to snowline and glacial retreat include the dangers imposed by the creation of new moraine or ice-dammed lakes (Morales 1966, 1969, 1979; Lliboutry 1975, 1977; Lliboutry et al 1977a,b), longterm impacts on highland–lowland water and power supply, and potential impacts on tourism.

The present study replicated a 1936 photograph of Yanapaccha peak (Figure 3; 5460 m) from an elevation of 4530 m (Figure 4), on 8 September 1997 at 12:12 PM (focal length: 35 mm). The dramatic loss of several hundred meters of ice cover on Yanapaccha during the past 61 years is clearly evident, as well as on the smaller peak to the right, where the 1936 glacier cover is now completely absent.

Two new torrent-like features are also apparent; little additional large-scale geomorphic change (eg, slumps, gullies, torrents) appears to have occurred. Out of the camera's field of view to the right, however, is the road over the Portachuelo de Llanganuco built in the early 1970s, as well as several new trekking and climbing trails to Pisco peak (a popular acclimatization climb).

Little change in the *Polylepis* groves to the lower left of the photographs can be seen, a positive finding that also provides an entry point for better understanding the dynamics of local forest use within this particular

TABLE 1 Sample plot attributes, Pisco Valley.[a]

Species	Number/ plot	Basal/ ha (m^2)[b]	Relative density (%)[c]	Relative dominance (%)[d]	Average dbh (cm)	Number seedlings	Number dead
Polylepis	89	59.5	90.8	98	14.5	30	6
Gynoxis	9	1.2	9.2	2	8.08	0	1

Size class (cm)	Number/plot	% total
4–12	48	54.0
12–20	21	23.0
20–28	13	14.6
28–36	2	2.2
36–44	2	2.2
44–52	1	1.0
52–60	1	1.0
60–68	1	1.0

[a]Date: 20 May 1998; plot size: 400 m^2; altitude: 4530 m; aspect: 186°; geomorphology: ancient boulder field/debris slide, boulders 2–3 m+ in diameter, moss capped; description: dense *Polylepis* forest, ~70% canopy cover, abundant deadfall, some evidence of fire, continuous groundcover of thick (10 cm+) and fragile moss/detritus, relatively abundant deadfall with no evidence of fuelwood collection, abundant *Polylepis* and *Gynoxis* seedling invading grassland to within 50 m of forest boundary.
[b]Basal area (m^2) per hectare, total area outline of trees near the ground surface.
[c]Relative density (%), number of individuals of a species divided by total number of individuals within a plot × 100.
[d]Relative dominance (%), total basal area of a species divided by total basal area for all species × 100.

FIGURE 5 Q. Honda from Portachuelo (Kinzl, 1932)

FIGURE 6 Q. Honda from Portachuelo (Byers, 7 July 1998)

area of the Pisco valley. *Polylepis* forests are considered to be one of South America's most endangered forest ecosystems. They are of critical importance to endemic avifaunal biodiversity and comprise primary water catchment sources (Hjarsen 1997). Less than 3% of the potential *Polylepis* forest in Peru is thought to remain today, with widespread removal linked to historical anthropogenic disturbance, fire from seasonal pasture burning (which continues to inhibit forest regeneration), and the abandonment of traditional Incan management systems with the arrival of the Spanish *Conquista* in the 1500s (Fjeldså and Kessler 1996).

Park authorities suggest that preservation of this particular forest in the Pisco valley is the result of management interventions imposed since 1975 (Valencia, personal communication), and recent efforts to reestablish *Polylepis* along trails and hillslopes were observed. Ground-truth examination within the forests, however, shows that they are located on ancient blockfields, which, by all appearances, are and have been for centuries inaccessible to cattle. The results from a 400-m^2 sampling plot (Table 1) show that natural regeneration processes are high within the forest zone, and large numbers of healthy *Polylepis* and *Gynoxis* seedlings and saplings were observed within the grasslands (also inaccessible to cattle) for up to 50 m from the forest edge. In contrast, high levels of cattle-

FIGURE 7 Huaraz from San Cristóbal (Schneider, 1939)

FIGURE 8 Huaraz from San Cristóbal (Byers, 10 September 1997)

induced seedling mortality were observed within the nonprotected and grazed areas at lower elevations within the valley.

Interviews with local cattle user groups would provide additional insights regarding traditional usage patterns, forest and nontimber forest products, current demand, and the impacts of more recent park policies. Likewise, the current uncertainty regarding contemporary forest change throughout most of the Huascarán National Park warrants a much greater areal coverage and analysis.

Honda Valley from Portachuelo
Date: 7 July 1998
Time: 1:15 PM
Altitude: 4725 m
Aspect: 230°
Map photopoint number: 2
Original: 1932, Leica B1, number 335, Kinzl

The Honda valley road was reportedly built in 1990 (Figure 6). Prior to that time, access was limited and the valley was used primarily for grazing. A comparison between Figures 5 (1932) and 6 (1998) shows several landscape changes, including (1) the road itself, (2) an increase in cultivated area and number of enclosed fields, and (3) the loss of *Polylepis/ Gynoxis* forest cover in at least two areas (ie, debris cones at lower center of photograph). There are no permanent villages in the upper valley, and local people walk, ride, or camp at the agricultural field sites on a daily basis. Farther up valley, and out of the photograph's field of view, is the mining road (reportedly built around 1994) that switchbacks steeply up Quebrada Cancahua.

The Honda valley is one of the few sites surveyed in the park where a loss of native forest cover was documented, as most others exhibited either no change or an increase in cover during the past 60+ years. Local informants suggested that both forest loss and the increase in enclosed agricultural plots have been linked primarily to the area's increased accessibility and thus to increased demand on resources during the past 8 years. This is in need of further verification, although most of the other valleys surveyed in this study have not had motorable roads built within them and remain relatively isolated. However, the numerous remnant *Gynoxis* groves and individual stems observed throughout the valley suggest that forest or woodland cover was greater in the past, and this is also in need of further study.

Huaraz from San Cristóbal
Date: 10 September 1997
Time: 11:15 AM
Altitude: 4505 m
Aspect: 200°
Map number: 3
Original: 1939, Plate Box 31, number 1, Schneider

The city of Huaraz, now a popular tourist destination, has sustained two major catastrophic events during the past 60 years—the 31 December 1941 outbreak of two cascading glacial lakes in the Quebrada Cojup to the west, killing some 4000 people, and the 31 May 1970 Huascarán earthquake (Richter scale: 7.7 magnitude), which, in addition to causing massive destruction throughout much of the region, killed an estimated

20,000 people in Huaraz while leveling much of the old city. Most of the traditional adobe brick architecture has since been replaced by concrete, with the exception of a few remaining enclaves identical to those greeting the German/Austrian expedition members in 1932 (Kinzl and Schneider 1950).

This trend continues within the rapidly growing city of Huaraz, the extent of which can be better appreciated by comparing Figures 7 and 8. Figure 7 shows a view of the Huaraz valley taken in 1939 from San Cristóbal, a prominent outcrop west of the city at an elevation of 4505 m. Figure 6 shows the replicate taken on 10 September 1997 at 11:15 AM (focal length: 35 mm). Judging from the shadows on the rock in the foreground, the replicate 1997 photograph appears to have been taken at least 2 hours later in the day than that of Schneider's original. Smoke and haze from pasture burning also obscure the distant horizons in the 1997 photograph, although several distinct landscape changes can be seen.

Foremost is the dramatic growth of Huaraz, a mostly forest-covered basin in 1939 that had become completely urbanized by 1997. The lack of photographs from the intervening decades prevents a better understanding of temporal as well as areal trends since 1939, although the use of available vertical aerial photos could be used for this purpose. Tree cover appears to have increased substantially within the larger valley, primarily a result of the promotion of exotic *Eucalyptus globulus* and *Pinus radiata* plantations since the 1930s. Reportedly, the use of native species (eg, *Polylepis* ssp, *Alnus acuminata*) has not been advocated by foresters working in the region since the early 1900s, although their reintroduction for enhanced water catchment, ecosystem preservation, nontimber forest products, and erosion control is now being strongly advocated (Hjarsen 1997).

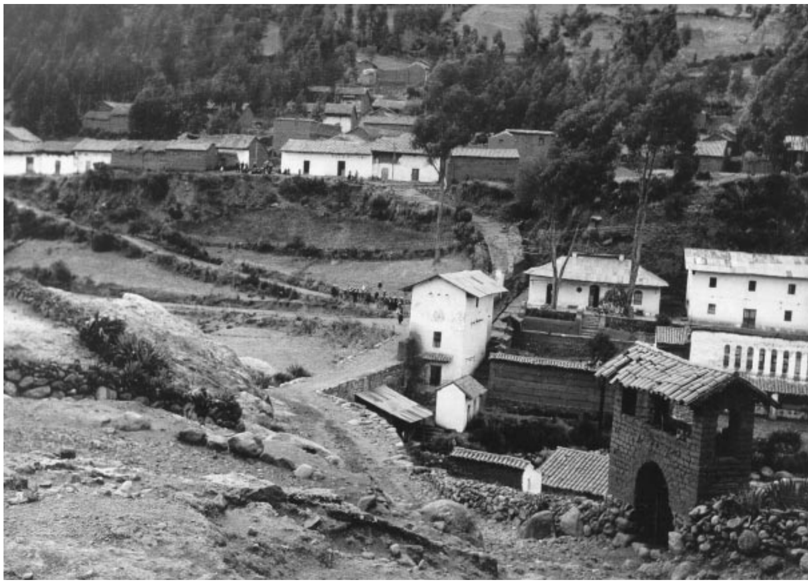


FIGURE 9 Olleros village (Kinzl, 1936)

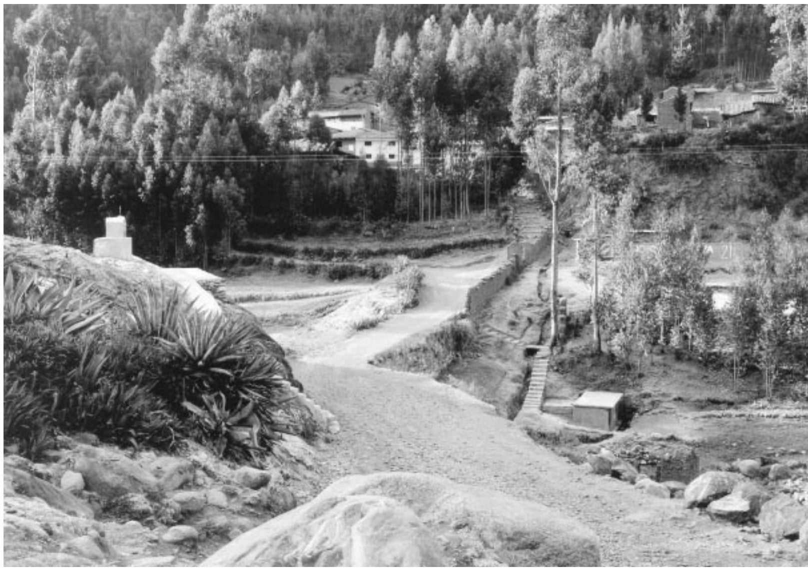


FIGURE 10 Olleros village (Byers, 11 September 1998)

Olleros village

Date: 11 September 1997
Time: 4:00 PM
Altitude: 3633 m
Aspect: 320°
Map number: 8
Original: 1936, Leica B4, number 135, Kinzl

Larger-scale photographs of village scenes can show a significant amount of detail related to contemporary changes in the cultural landscape, perhaps most dramatically evident when viewed in terms of the impacts of catastrophic events and changes in forest cover. In partial illustration, the village of Olleros, south of Huaraz, is shown in a 1936 Leica photograph taken by Hans Kinzl (Figure 9), with the 1997 replicate shown as Figure 10 (11 September 1997, 4:00 PM; focal length: 35 mm). The most obvious cultural change in the photograph is the absence of the 1939 housing structures near the bridge in the foreground, nearly all of which were leveled in the 1970 earthquake. Local informants remembered the two white buildings at the extreme right-center of Figure 11 as a rented high school prior to 1970, owned by a family that lived in the third white building on the old bridge. The adobe structures in the foreground were used for the produc-

FIGURE 11 Ticapampa from the Cordillera Negra (Kinzl, 1936)

FIGURE 12 Ticapampa from the Cordillera Negra (Byers, 6 July 1998)

tion of mineral water; the spring is still active today and is protected by the small box-like structure shown in the 1997 photograph. The remaining white building with the lattice-type windows to the extreme right of center was most likely dismantled at some point well before the 1970 earthquake, as none of the informants could recall its presence prior to that time.

Nearly all of the housing above the river appears to have changed, again most likely because of the 1970 earthquake, although most of the upper village is now masked by the widespread increases in *Eucalyptus* sp cover. This is particularly conspicuous in the extreme right-center of the 1997 photograph and upon the background hillslopes, now under a continuous plantation cover of approximately 40-year-old trees. The bridge is one of the few features that has remained intact, a feature reportedly present at the time of the town's creation in 1909, although the foreground has changed as a result of blasting and road reconstruction during the early 1970s. Other features of note include an increase in cactus growth to the left and the presence of the power lines installed in the late 1970s.

Ticapampa from the Cordillera Negra

Date: 6 July 1998
Time: 2:34 PM
Altitude: 3745 m
Aspect: 75°
Map photopoint number: 9
Original: 1936, Kinzl

As in many regions within the Rio Santa valley, there were no trees in Ticapampa village in 1936, in contrast to an abundance of *Eucalyptus* sp in ravines, along the riverbank, and within the village by 1998. Several other notable landscape changes include glacial recession of the distant Cordillera Blanca, village growth, and mining tailings from the Ticapampa mine (now inactive). More terraces and enclosed plots seem to have been in use in 1936, many of which are now abandoned. Pasture conditions on the hillslopes above (east of) the village may have improved during the past 62 years—these slopes appear to have been more gullied and eroded in 1936 than in 1998, with a more continuous groundcover now apparent.

Discussion

The replication of 10 photographs from the 1936 and 1939 German and Austrian expeditions has established a selected, site-specific baseline for landscape change interpretation and monitoring within the Huascarán National Park and buffer zone. The sample size is small, more work is needed, and extrapolations to other areas within the study region must be treated with caution. Nevertheless, several important insights were obtained related to change or nonchange in native forests, non-native forests, glaciers, grazing impacts, and urbanization trends. Although only 5 of 10 pairs of photographs have been described in this paper, the following discussion is based on all 10 pairs obtained in the study.

Forests

Contrary to popular opinion, the *Polylepis* forests within the Pisco valley, Q. Cohup, Q. Shallap, Q. Rajucolta, and L. Querococha appear to have remained stable after more than 60 years of local use, even in the vicinity of heavily grazed pastures. Most appear to have increased slightly in area. Judging from the number of seedlings observed, promising regeneration attributes exist both within and outside of most forested areas. Assuming that the majority of forests surveyed are remnant forests remaining from prehistoric and historic deforestation processes (Chepstow-Lusty et al 1998), forest stability during the past 60 years might be linked to (1) the relative inaccessibility of forests and/or (2) favorable site-specific attributes of ancient rockfalls and boulder fields, such as the retention of heat. As mentioned, large numbers of healthy *Polylepis* and *Gynoxis* seedlings and saplings were also observed in the non-grazed grasslands adjacent to the *Polylepis* forests in the Pisco valley. In contrast, few seedlings were observed in the grazed and lower elevation forests, and high levels of seedling mortality were observed within most of the valley's afforestation project sites (eg, along the Pisco basecamp trail, hillslopes, and bottom lands).

A *Polylepis/Gynoxis* forest within the Honda valley, however, appears to have been removed at some point during the past decade. Informants linked its removal to the impacts of road building, increased accessibility, and increased resource demand since the early 1990s. On the other hand, forests within the easily accessible Querococha region, where a motorable road has existed since the early 1900s, do not appear to have changed significantly during the past 60 years. Further surveys will be required to determine how strong the accessibility/deforestation correlation may or may not be for other regions of the park.

Interviews with local cattle user groups are suggested for the most detailed understanding of forest change, traditional forest utilization patterns, forest and nontimber forest products, current demand, and impacts of park policies since the 1970s. Likewise, afforestation initiatives within the park might also benefit from a systematic identification of other naturally regenerating *Polylepis* zones within the park, such as within the Pisco valley, and use of these sites for future restoration initiatives.

Nonnative forest increase

Eucalyptus globulus and *Pinus radiata* forest cover has increased substantially throughout the Huaraz valley (Figures 7, 8) and Olleros region (Figures 9, 10). *Eucalyptus* was introduced to Ticapampa (Figures 11 and 12) at some point after 1936 since none were present in the 1936 photograph. As mentioned, *Eucalyptus globulus* and *Pinus radiata* forest propagation has been heavily promoted and practiced throughout the Cordillera Blanca and Negra since the early 1900s. Today, hundreds of hectares of newly planted *Eucalyptus* seedlings can be seen on hillslopes throughout the Cordilleras. Despite a desire in some sectors to promote the use and re-establishment of native *Polylepis* and *Alnus* species, *Eucalyptus* and *Pinus* appear to have become firmly established as part of the contemporary cultural landscape. Contributing factors may include their relatively rapid growth, hardiness and drought resistance, and provision of badly needed fuelwood, structural timber and shade. No studies related to associated nonnative forest impacts (eg, on groundcover, accelerated soil loss, and biodiversity), however, are known to exist for the region.

Glaciers

Glacial recession, a phenomenon of concern throughout the Cordillera Blanca, was documented in this study by the replicated photographs for Pisco valley, Q. Shallap, Olleros/Huantsán, and Yanamarey. A dramatic loss of ice and snow during the past 60 years was clearly evident for each site. The construction of access roads, trails, living quarters, and dams has occurred in the vicinity of many glacial lakes since the 1950s as part of ElectroPeru's glacial lake control program (Ames 1998). Vegetation changes noted within these upper valley regions include the recolonization of catastrophically drained and mechanically lowered glacial lakes by *Baccharis tricuneata, Gynoxis* sp, *Lupinus* sp, *Ageratina azangaroensis*, and *Polylepis* sp.

Grazing impacts

As elsewhere in the park, Quebradas Honda, Cohup, Shallap, and Rajucolta are heavily grazed and controlled by individual user groups. Locked gates exist at most valley entrances, and trekking/climbing groups are often charged entrance fees. The heavily grazed appearance of most valleys, often up to snowline, can be a surprise (and disappointment) to visitors used to a more wilderness experience in other national parks. While grazing impacts are conventionally thought to be deleterious throughout the region, certain hillslopes near Ticapampa (Figures 11, 12) and L. Querococha now appear to exhibit a more continuous groundcover of grass and herbs than before. Unfortunately, the scale of the photographs replicated for these valleys is too small to permit a more detailed assessment of grazing impacts during the past 60 years. Individual hillslope and plot-level repeat photography, however, are standard monitoring and evaluation methods that have recently been incorporated into the Olleros range/pasture project (Parque Nacional Huascarán y Instituto de Montaña 1998).

Urbanization

Figures 5 and 6 illustrate the dramatic growth of Huaraz since 1939, then largely forest-covered and now a completely urbanized basin. Increases in village size were also noted for Olleros (Figures 9, 10) and Ticapampa (Figures 11, 12). Such growth is expected to continue and accelerate with the recent increases in mining activity and tourism. Although this study focused primarily on physical landscapes, the future replication of older photographs of Huari, Pomabamba, Huaraz, and San Luis should provide additional cultural landscape change information of interest and practical utility.

Clearly, a greater area of the park and buffer zone must be studied before a more definitive understanding of landscape change processes can be obtained. Future replication of historic photos is planned in the Cordilleras Blanca and Huayhuash (Byers 1998:20). Results from the present investigation, however, also raise a number of important management-related questions that need further study.

1. Little quantitative information exists regarding *Polylepis* forest regeneration trends and factors of influence, such as accessibility, the impacts of cattle grazing, and predominant location on boulder fields.
2. Correlations between recent road construction and forest loss within the park are poorly understood.
3. The spread and promotion of nonnative *Eucalyptus* and *Pinus* forests throughout the buffer zone has provided tangible benefits such as fuelwood and structural timber, but little is known regarding nonnative forest relationships to groundcover, soil loss, and biodiversity.
4. The reintroduction of native *Polylepis* and *Gynoxis* forest is solidly endorsed by the park but may require different strategies and methods to increase seedling survivability while encouraging adoption and protection by local communities.

Conclusion

Although preliminary by design, the present study produced several new insights related to landscape and land use change phenomena within the Huascarán National Park and buffer zone. They include indications of an apparent stability and, in some cases an increase, of native *Polylepis* forest cover, a significant regional increase in nonnative *Eucalyptus* and *Pinus* forest cover, widespread glacial recession, improved pasture conditions (in some areas), and increased trends in regional urbanization. The utility of results from the present and future studies will be improved by the addition of detailed ground truth disturbance analyses, in-depth participatory interviews with local people, collaboration with regional colleagues and specialists, and detailed literature reviews. Additional questions of importance can be expected to arise during the course of these investigations. Increasing the historic photographic and quantitative database for the Huascarán National Park and buffer zone, however, will continue to provide important information to practitioners concerned with contemporary landscape change processes, human versus natural impacts, and future management and restoration options.

AUTHOR

Alton C. Byers, PhD
The Mountain Institute, PO Box 907, Franklin, WV 26807, USA.
abyers@mountain.org

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