Climate change, food sovereignty and ancestral farming technologies in the Andes

Running title: Food sovereignty and farming technologies in the Andes

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FAO: Food and Agriculture Organization of the United Nations
INFOODS: International Network of Food Data Systems
IPCC: Intergovernmental Panel on Climate Change
PACC: Climate Change Adaptation Project

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Abstract:

Indigenous people are among the most vulnerable populations to climate change. However, indigenous societies' potential contributions to climate change and related issues of food security are vast but poorly recognized. The objective of this report is to inform the nutrition and public health communities about the potential contributions of ancient Andean technologies to addressing these contemporary challenges. Our research examines these ancient farming technologies within the frame of climate change and dietary potential. Specifically, we focus on four technologies derived from three case studies from Ecuador. These technologies were analyzed using evidence mainly of adaptation to climate change in indigenous-based agriculture. Our examination of these technologies suggests they may be effective mechanisms for adapting to climate change and protecting food sovereignty. Thus, while highly vulnerable to climate change, indigenous peoples in the Andes should also be seen as “agents of change”.

keywords: food sovereignty, climate change, ancestral farming technologies, Andes

Introduction:

For over a decade, the Intergovernmental Panel on Climate Change (IPCC) has highlighted the consequences of climate change in rainfall and temperature, along with increasingly severe weather events. These consequences jeopardize the survival of humans as climate change directly affects agricultural production, food security and nutrition (3). This scenario, as conveyed by scientists worldwide, represents a “Climate Emergency” (33).

Paralleling Western science, changes in weather and climate patterns have been observed and understood by indigenous societies from around the globe, in part because of their often extreme reliance on nature (18). Indigenous people are also considered among the most vulnerable
populations (16), partially because of their limited access to modern technology. Nevertheless, as the IPCC has recognized, indigenous knowledge is pivotal to adaptation to climate change (30).

In this context, our contribution focuses on ancient farming technologies still being used by indigenous Andean populations. These technologies, while increasing exponentially the quantity of crops produced, also guard against phenomena associated with climate change, such as soil erosion, drought, hailstorm, frost, and flooding. Furthermore, they are capable of supporting a variety of highly nutritious crops, thus improving access to healthy, culturally adequate and nutritiously rich foods within indigenous communities.

Methods:

Population

The Andes is both a geographic and cultural area, with Andean populations sharing many cultural traits even among geographically distant places of Peru, Ecuador, and Bolivia. According to the most recent national censuses in Peru (2017), Ecuador (2010) and Bolivia (2012), indigenous people represent, respectively, 26%, 7% and 40.6% of each countries’ populations (19; 20 & 21). Indigenous people in these three Andean countries are mainly concentrated in the rural sector. Indigenous settlements are located across the geographic spectrum, from the high Andes to the Amazonian lowlands, and in Peru and Ecuador, in coastal regions. Currently, these populations embody the paradox of being key actors in the region’s food system (39) while disproportionately experiencing food insecurity and chronic undernutrition (33).
Conceptualizing climate change in Andes

Climate change in the mountainous Andean areas is having a profound impact on food security by affecting water sources and crop production. Climate change is rapidly melting glaciers that provide water for human consumption and for agrarian activities in the Andean lowlands (24). Intense rains increase the risk of landslides, as well as flooding, posing a serious risk to harvests (31 & 18). Rains alternating with extreme droughts also affect growing cycles (9 & 31). Finally, crops in the mountainous areas of Andes are especially susceptible to frost (9 & 26) and hailstorms (9). In the northern Ecuadorian Andes, ashfalls from recurrent volcanic events does also represent a big hazard to agriculture. These combined effects of climate change and other natural disasters compromise food security, particularly among indigenous populations often highly dependent on subsistence agriculture.

Procedures

We conducted a retrospective, observational and integrative study combining: (i) secondary information sources that met the twofold criteria of current usage and adaptative capacity of a technology; (ii) three relevant, independent, primary research experiences in Ecuador, representing firsthand experience with four ancient farming technologies currently active; and (iii) plant species grown using ancient farming technologies, with reference to the micronutrient content of these species.

Secondary information sources included published articles in peer-reviewed journals (e.g. regulation and reports by government and international organizations), and gray literature (non-governmental organizations reports, grassroots and media). Primary research represented three studies in Ecuador over the last two decades (Image 1). Co-authors of this report directly participated in these three studies, which represent direct access to the methods, data and documentation of the agroecological spaces and communities that rely on active ancestral technologies in active use today (Image 2). While the studies had different objectives, methods
and populations, all included structured and semi-structured observations allowing for a detailed description of ethnographic and agroecological landscapes (“anonymous for peer-review process”). The first study, in the Santa Elena Peninsula and the Guayas Basin (late 1990s and early 2000s), was part of a community-based applied archaeology and heritage empowerment project. The second study, in an indigenous rural community of the central highlands (April to December 2018), included a mixed-methods design site analysis that accounted for sunlight and water patterns, architecture (in the agroecological sense), slope of the terrain, and agrobiodiversity. The third study (June to July 2019) was a qualitative exploration of urban agriculture in Quito focused on agriculture, food sovereignty and climate change, including site visits to indigenous populations who have settled on hillsides in the periphery of the city.

Image 1. Map indicating the three studies’ sites
Results

From the integrative analysis, we identified four important ancestral farming technologies that are highly applicable to climate change adaptation—terraces, waru-waru (raised beds), qochas and albarradas (jagueyes) (two types of reservoirs). Because changes in rainfall patterns is one of the greatest threats posed to agriculture by climate change, ancient water management techniques such as these are crucial adaptive technological responses. Each of these practices is also associated with the production of key foods in indigenous diets.

Terraces

Terraces have been central to Andean agriculture for more than two millennia (26). In their most basic form, terraces are constructed platforms on mountain slopes, connected by water channels (6). During the 14th and 15th centuries, the Incas improved this ancient technology by incorporating underground aqueducts and complementary irrigation systems (6; 8 & 36). In Peru, terraces cover an estimated 2 million hectares; however, only 25% are still in use (36). The terraces are built on a soil and clay base that helps to prevent water loss (36), promoting the optimal use of water resources, preventing soil erosion caused by heavy rainfall, and reducing the impact of frost and cold winds (1 & 36). Terraces have the potential of increasing food per production unit; according to Altieri (1996: 3) “first year yield data from new bench terraces showed a 43–65% yield increase in potatoes, maize, and barley compared to yields of these crops grown on sloping fields.”

The literature is consistent with our experiences in the field; in the case of the community in the central highlands, informant testimonials affirm that the terraces are pre-Incan and have maintained a steady food production from past to present by protecting crops and soil from the effects of heavy rains, frost, wind and hail. In the case of hillside farms in Quito’s periphery, the terraces are in a constant process of reconstruction due to urban development, but also represent a convergence of indigenous ecological knowledge with agroecology and permaculture.
technologies. This combination of ancestral technologies and more modern strategies have produced foods free of agrochemical inputs and pesticides, both for subsistence and sale in organic farmers markets for over a decade. In both cases, it is strikingly how terraces support highly diverse polycultures characterized by ecological interactions, water retention traps through swales and green matter, and notably reduced angles in the slopes.

*Waru-waru (wachos, camellones, raised fields or raised beds)*

The waru-waru are appropriate in flood prone areas, such as those in Lake Titicaca shared by Peru and Bolivia (13 & 36) and in coastal areas in Ecuador (10). The waru-waru represent a technology that helps to balance the level of moisture on the soil for cultivation of tubers and grains, while increasing soil fertility (13). Waru-waru are a series of raised beds connected by a network of earth channels that prevent or delay flooding, while maintaining crop yield during periods of drought due to the moisture stored in the soil (10 & 36). From a climate change perspective, this technique also reduces the impact of frosts; due to the biomass effect; the canals absorb the sun’s heat in the morning and radiate it back at night (13). The raised beds also diminish the effects of the el Niño that floods most of the lowlands areas, allowing traditional crops such as maize and tubers to remain above flood levels.

Waru-waru also maximize productivity by using the water channels to raise aquatic fauna (fish and waterfowl) and cultivate plants adapted to humid or wet environments, such as rice (2). The plants and animals living in the channels not also provide protein, they act as fertilizer for the polycultures grown on the beds. In addition, this technique results in more nutritious harvests, as well as high yields per unit of land cultivated (13 & 32). While historical processes and migration have significantly reduced the use of raised fields in coastal Ecuador (10), they remain associated with key crops such as maize, sweet potato, squash and cassava, different varieties of fish, ducks and geese, and charapa turtles.
Qochas and Albarradas

The qochas and albarradas are similar technologies developed in distinct ecological regions to store water. Both technologies use sloping land to catch water and channel it to a qocha or albarrada where water accumulates. The qochas system of the highlands allows soil management that improves fertility, while water storage allows ancient Andean highlanders to farm (34). Similarly, albarradas, found in middle and lower elevations just below Ecuador’s dry forests (10) store water during rainy season, when there is an excess of water for use during the dry season. In sum, both qochas and albarradas act as a water storage devices in combination with pasture, crops and feed for animals.

In the context of unpredictable rainfall concurrent with climate change, water retention and management is a critical adaptive farming technique. While the function may be the same, the techniques were developed to operate in specific altitudinal zones and ecosystem contexts, resulting in important distinctions. For example, the qochas of the high Andes receive water absorbed from the moisture of the environment through the paramo ecosystem. As such water is channeled to the qochas, from where it is distributed to the lowland areas. In contrast albarradas are located in dry forest, strategically positioned at the base of the slope to retain runoff water (28).

Both water retention systems allow indigenous community flexible control of rainwater in areas facing severe droughts interspersed with intensive flooding events (10 & 34). Qochas, in particular, moderate the microclimate in its surroundings, generating more moisture and allowing native vegetation to grow (34). In our ethnographic community research, we observed communities in the central highlands working together to recover and restore qochas, an important strategy to promote ecosystem restoration and greater water availability. In addition to water for crop production, the coastal region’s albarradas serve as an oasis during the dry season, helping both domestic and wild animals survive.
Food security with food sovereignty in Andes

The importance of ancestral technologies such as those discussed above is seen in the wide diversity of nutrient rich crops the technologies support in these traditional agroecosystems. Andean farms, according to Altieri and Koohafkan (2008), grow an average of 34 different crops; in some areas, farmers cultivate as many as 50 varieties of potatoes in their plots, while their communities may have up to 100 local varieties. This wide variety and genetic variability is positively adaptive, because it decreases the threat of crop loss due to pathogens and pests (3). Through the literature and field observations, we documented 36 indexed crops that support food sovereignty and that are regularly grown using these ancestral technologies. Table 1 presents the micronutrient content in 100 grams of key foods produced using ancestral technologies (14) , a critical consideration given serious nutrient deficiencies affecting indigenous populations (32).

Ancestral farming technologies represent an important link with crops culturally accepted that also diversifies local communities’ diet, which are critical considerations related to food sovereignty. Concurring with Kulhein (2003: 39) “the traditional food systems of indigenous peoples contain a wealth of micronutrients that have been poorly described and reported in scientific literature.” Consequently, it is important that the nutritionally rich agri-food systems defined by ancestral technologies are leveraged to address the important micronutrient deficiencies experienced by many indigenous populations (32).
2. Studies’ sites and ancestral technologies (Collague of photos: labels in each photo)

Discussion

Ancestral farming technologies, discussed beyond the perspective of adaptation and mitigation of climate change and food sovereignty, are essential to halt the expansion of the agrarian frontier by ensuring the essential ecological services acting as mitigation mechanism (1). Furthermore, the Food and Agriculture Organization (FAO) and the Globally Important Heritage Systems (2020: n.p) state that “Andean agriculture is one of the best examples of the adaptation and knowledge of farmers to their environment for more than 5000 years” (15). Andean crops have a high level of resistance to environmental variation (30), but this
tandem analysis of the literature and primary research in Ecuador shows that indigenous people are key players in preserving and promoting ancestral farming technologies.

Evidence presented and discussed suggests that these technologies can be important, effective mechanisms for adaptation to climate change, providing micronutrient dense traditional diets to indigenous communities, at the same time maintaining the symbolic value of these technologies. From a climate change mitigation perspective, these ancestral farming and water management techniques have proved to enhance diversity and reduce soil erosion, and consequently, it does not rely on pesticides and fertilizers derived from fossil fuels that are among the main source of greenhouse emissions (4). Combining analysis of agriculture and nutrition in the face of climate change is very important to develop sustainable food systems and ensure food security (38).

Growing interest in these ancient technologies from international and governmental organizations is helping move towards their incorporation in public climate change policies. For example, in 2007, Bolivia formally incorporated indigenous ecological knowledge in their National Climate Change Adaptation Mechanism policy (36). In Peru, indigenous ecological knowledge was used in the formulation of the Second National Communication on Climate Change in 2010, while the Ministry of Agriculture itself is building 50 qochas in Cusco to address climate change (7). In Ecuador, indigenous ecological knowledge is recognized in the 2008 Constitution, while the Ministry of Environment incorporated ancestral technologies in the Climate Change Adaptation Project (PACC) (12). Ecuador’s Water Management Secretariat promoted construction of albarradas in Santa Elena to provide water for cultivation, requiring that albarradas be built using ancient technologies because of their greater efficiency.

Regardless of whether waru-warus are considered a relic technology, it is in use. Programs for recovering ancestral technologies have proved, both at the lower Guayas Basin in Ecuador and around the Titicaca lake, to be an important tool for maximizing crop output. Nevertheless, it is important to mention that the efforts to reintroduce this technique in the Titicaca area were not
so successful, which helped to create awareness of the importance of putting greater effort in re-
introducing this technology to meet desired outcomes (35). Some of the explanations of the
unsuccessful re-introduction of the technique expose the disconnection from the ancestral
memory. However, it is important to mention that some communities were given the
opportunity to re-use such technology, which resulted in success in Manabí and Santa Elena in
Ecuador (13,11 & 28).

Promotion of Andean ancestral technologies has the potential to provide local communities with
tools to adapt and mitigate climatic change while enhancing food production. The technologies
discussed here represent sustainable methods that promote both agrodiversity and the
production of nutritious food for often food-insecure populations. In this context, it is relevant
to consider the connection between the ancestral farming technique with traditional crops and
the nutritional benefits these crops provide to the community’s health. This topic remains
poorly reported in scientific literature, and it is important to recognize that indigenous peoples’
traditional knowledge could help to mitigate and adapt to climate change while securing
micronutrient rich diets. Consequently, indigenous people have the capacity to shift from being
among the most vulnerable to becoming agents of change, capable of contributing to the climate
change challenge while simultaneously contributing to food security and food sovereignty in the
region and beyond.

**Contribution statement:**

ACT designed the research with support of CAGR; ACT conducted research with comments
from CAGR, FDE and MS; ACT analyzed data with support of CAGR; ACT wrote the paper
with inputs from CAGR, FDE and MS; ACT, CAGR, FDE and MS reviewed the draft;
ACT had primary responsibility for final content. All authors read and approved the final
manuscript.
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| English Name        | Scientific Name       | Agriculture Technique                 | Micronutrient Content In Micrograms (Mg) |
|--------------------|-----------------------|--------------------------------------|-----------------------------------------|
| Oca                | Oxalis tuberosa       | Terraces                             | Fe 1.84                                 |
|                    |                       |                                      | Ca 2                                    |
|                    |                       |                                      | P 36                                    |
|                    |                       |                                      | Vitamin C 38.4                          |
| Amaranth           | Amaranthus            | Terraces                             | Fe 530                                  |
|                    |                       |                                      | Ca 1                                    |
|                    |                       |                                      | K 800                                   |
|                    |                       |                                      | Ca 1                                    |
|                    |                       |                                      | Fe 0.11                                 |
|                    |                       |                                      | K 302                                   |
|                    |                       |                                      | P 24                                    |
|                    |                       |                                      | Zn 7                                    |
|                    |                       |                                      | Ca 32                                   |
|                    |                       |                                      | P 32                                    |
|                    |                       |                                      | Fe 0.50                                 |
|                    |                       |                                      | Ca 20                                   |
|                    |                       |                                      | P 57                                    |
|                    |                       |                                      | Zn 0.15                                 |
|                    |                       |                                      | Fe 0.60                                 |
|                    |                       |                                      | Ca 56                                   |
| Lupine beans       | Lupinus albus         | Terraces / Waru-waru                 | Fe 242                                  |
|                    |                       |                                      | P 3.30                                  |
|                    |                       |                                      | Zn 5.30                                 |
| Squash             | Cucurbita maxima      | Terraces / Waru-waru / Albarradas    | Fe 0.11                                 |
|                    |                       |                                      | Ca 87                                   |
|                    |                       |                                      | P 335                                   |
|                    |                       |                                      | Fe 10.80                                |
|                    |                       |                                      | Ca 1                                    |
|                    |                       |                                      | Fe 0.11                                 |
|                    |                       |                                      | K 284                                   |
|                    |                       |                                      | P 34                                    |
|                    |                       |                                      | Zn 0.17                                 |
| Pumpkin            | Cucurbita mixed       | Terraces / Waru-waru / Albarradas    | Ca 31                                   |
|                    |                       |                                      | P 21                                    |
|                    |                       |                                      | Fe 3.50                                 |
| Quinoa             | Chenopodium quinoa    | Terraces / Qochas                    | Ca 5                                    |
|                    |                       |                                      | P 59                                    |
|                    |                       |                                      | Fe 0.30                                 |
| Mortiño or Andean blueberry | Vaccinium meridionale | Qochas                               |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
| Cañihua            | Chenopodium pallidicaule | Qochas                  |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
| Passion fruit      | Passiflora nitida    | Waru-waru                            |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
| Chili              | Capsicum sp           | Waru-waru / Albarradas               |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
| Cassava            | Manihot esculenta     | Waru-waru / Albarradas               |                                        |
|                    |                       |                                      |                                        |
|                    |                       |                                      |                                        |
| Item               | Scientific Name                  | Ca | P   | Zn  | Fe  |
|--------------------|----------------------------------|----|-----|-----|-----|
| Bocachico fish     | *Prochilodus retieulatus magdalenae* | 45 | 477 |     |     |
| Tiger catfish      | *Pseudoplatystoma fasciatum*     | 308| 398 | 6.00| 380 |
| Sweet potato       | *Ipomoea batatas*                | 6  | 40  | 0.50| 30  |
| Ducks              | *Anas platyrhynchos*             | 15 | 188 | 1.36| 1.80|
| Geese              | *Anser*                          | 43 | 261 | 3.07| 30.53|

Micronutrients are sourced from INFOODS’s Latin American food composition tables.