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The impact of Inca Culture on bio-dynamic agriculture: a study of rock dust in Roraima, Brazil

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Abstract

In Peru, agriculture faces significant challenges due to climate change and the well-known effects of El Niño, which result from the warming of the Pacific Ocean. Indigenous historian Luis E. Valcárcel observed that the Andean civilization transformed an environment unsuitable for agriculture into a productive agricultural society. He described this as a tremendous effort that persisted throughout the Spanish colonial period but has since diminished, highlighting a strong yet fading connection between ancient and modern Peru.

More recently, researchers have identified rock dust as a highly nutritious fertilizer. A commonly used technique to enhance soil fertility combines moderate amounts of rock dust with larger quantities of cattle manure. Another well-regarded strategy for boosting food production is biological nitrogen fixation, primarily occurring at the roots or stems of plants and facilitated by bacteria associated with legumes.

In Roraima, Brazil, there is significant potential for using rock powder as a soil enhancer. However, its application remains limited due to a lack of technology, infrastructure, and educational support, particularly in remote areas within indigenous territories.

This study examines the interplay between culture, knowledge, intelligence, and biodynamic agriculture within two distinct yet interconnected models. The first is the Culture-Knowledge-Intelligence (CKI) model, which illustrates how culture influences knowledge and its application, or intelligence. The second is a biodynamic agriculture model, which emphasizes a sustainable approach to resource utilization on farms.

The findings indicate that Inca culture forms the foundation of the CKI model, encouraging small farmers to adopt family-based and cooperative agricultural practices. Additionally, the biodynamic agriculture model demonstrates that agricultural cooperatives serve as the cornerstone for this sustainable farming approach.

Keywords: *Family farming, cooperatives, knowledge management, cultural intelligence, rock dust.*

INTRODUCTION

The impact of Inca culture on agriculture remains insufficiently explored. Degregori and Sandoval (2007) outlined the historical development of anthropology in Peru, identifying five key stages: (1) literary indigenism; (2) the influence of U.S. culturalism; (3) the impact of development theories; (4) the influence of Marxism; and (5) the decline of the "Andeanist paradigm."

Valcárcel (2018) highlights the remarkable environmental adaptation of the Inca civilization, attributing their achievements to a culture of inventive ingenuity. López and Aguilar (2015) emphasize the enduring legacy of Inca agricultural innovations, such as terracing and irrigation systems, exemplified in sites like Ollantaytambo, Machu Picchu, Pisac, and Yucay. These constructions demonstrate the Incas' collective effort to harmonize with and dominate their environment.

Lothrop notes that South America, particularly the Andean region, may surpass other parts of the Americas in agricultural sophistication. Civilizations such as the Moche, Tiawanaku, Nazca, and Chimu laid a cultural foundation inherited by the

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Incas, who evolved into one of history's most significant civilizations (Valcárcel, 2018). Flores Galindo, in Looking for an Inca: Identity and Utopia in the Andes, highlights the unique historical memory of the Incas compared to other civilizations, observing that no equivalent to the Inca utopia exists for the Aztecs.

Milla Batres (1981) underscores the independent development of Andean civilization, a rarity in human history. López and Aguilar (2015) further detail the Incas' profound understanding of their environment, including celestial observation for weather prediction. This knowledge enabled practices like crop rotation, which prevented soil exhaustion and synchronized planting with seasonal conditions. Different crops—such as potatoes, corn, beans, and cotton—were cultivated based on geographic and climatic suitability, while the domestication of camelids, birds, and dogs supplemented food security and labor needs.

The foundation of Inca agricultural success was family farming, which remains relevant today. Addressing modern challenges like population growth and food demand requires investment in family farming, modern techniques, and cooperatives. Kumawat, Razdan, and Saharan (2022) project a 70% increase in agricultural production will be necessary by 2050 to sustain a growing population (Bandyopadhyay et al., 2017).

This article examines the adaptation of Inca cultural practices to biodynamic agriculture for family farmers. It introduces the Culture-Knowledge-Intelligence (CKI) model, linking cultural heritage to knowledge (contextualized information) and intelligence (applied knowledge). The proposed biodynamic agriculture model emphasizes cooperatives and government-supported technical assistance, acknowledging the challenges of transitioning from industrial to sustainable farming practices.

In Peru, climate challenges, particularly those exacerbated by El Niño, compound soil quality issues. This article discusses soil remineralization through rock dust and biological nitrogen fixation, cooperative farming benefits, and the integration of the CKI model into biodynamic agricultural strategies.

The highlights of the article are:

1. Volcanic rocks with basic compositions, such as basalts and diabases from Brazil's Serra Geral Formation, are particularly effective due to their high calcium, magnesium, and iron content (Bergmann & Holanda, 2014)
2. Inca culture is suitable for the use of biodynamic practices because it is based on collaboration and respect for nature.
3. There is evidence that the mixture of rock dust and cattle manure has high nutritional potential for plants.
4. More training and support with machinery is still needed to consider rock dust as a biodynamic practice
5. The Brazilian government must support the poorest regions of Brazil with research and training in relation to rock dust as they are unable to import fertilizers. Its importance is great in countries like Brazil, which imports around 65% of the raw materials needed to manufacture fertilizers and presents a worrying projection of demand over production in this sector, which is expected to reach 83% in 2025 (Bergmann & Holanda, 2014),

Article Structure

Introduction: Overview of Inca agricultural practices and their modern relevance.

Soil Remineralization: Examines rock dust and biological nitrogen fixation techniques.

Cooperatives and Biodynamic Agriculture: Explores the role of cooperatives as a foundation for sustainable farming.

CKI Model: Develops a theoretical framework connecting Inca culture to biodynamic agriculture.

Conclusion: Summarizes findings and proposes future applications of the CKI model for family farming initiatives.
This work provides a theoretical basis for applied research, offering insights into sustainable farming methods grounded in cultural heritage.

Theoretical background

1. Rock dust and biological fixation of nitrogen

Farmers familiar with the rock-dust technique often adopt it to reduce costs and increase agricultural production. This technique holds significant potential for family farming due to its lower financial risk and decreased reliance on imported chemical fertilizers (Parikoglou, Emvalomatis, & Thorne, 2022). Additionally, rock dust minimizes environmental damage caused by chemical fertilizers, such as soil and water pollution (Silva et al., 2020).

Ramos et al. (2022) highlight that chemical fertilizers are closely tied to the use of chemical pesticides, which harm soil microfauna—crucial for organic matter decomposition and nutrient cycling—and accelerate the loss of organic carbon, released into the atmosphere as carbon dioxide.

Indicative research suggests that rock dust can be applied to various crops in particle sizes ranging from 0.105 to 4.0 mm, similar to limestone, using manual or mechanized methods. Application rates vary depending on the soil type and crop, ranging from 0.5 to 8 tons per hectare. Volcanic rocks with basic compositions, such as basalts and diabases from Brazil's Serra Geral Formation, are particularly effective due to their high calcium, magnesium, and iron content. These nutrients are readily available when the rocks are crushed to the appropriate particle size (Bergmann, 2014). Alkaline rocks rich in potassium and volcanic terms with microcrystalline matrices are also highly suitable for soil remineralization.

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Different rock types provide various nutrients depending on their composition, soil conditions, and crop requirements. However, the relationship between specific rock types and crop performance requires further research. Soil remineralizers can originate from rocks with diverse chemical compositions, but their broader potential—such as using rock dust to replace cement in concrete—has also been explored.

Rock dust releases nutrients gradually, offering advantages over chemical fertilizers, including longer nutrient retention in the soil (Theodoro & Leonardos, 2006). This slow release supports increased agricultural productivity, lowers production costs, and mitigates environmental impacts such as soil and water resource pollution (Silva et al., 2020).

A promising approach involves combining intermediate doses of basalt powder with larger amounts of bovine manure (Viana, Caetano, & Pontes, 2021). This technique, also supported by Camargo et al. (2012), has shown that rock dust is most effective when paired with organic fertilizers. Despite its potential, the use of rock dust in Brazilian agriculture remains underexplored and requires further research, particularly to assess its agronomic effectiveness when combined with animal manure.

In Brazilian family farming, rock powders are typically used alongside organic residues such as animal and green manure. Many farmers produce these inputs through composting processes enriched with microorganisms, enhancing nutrient extraction efficiency (Bergmann, 2014). This synergy between rock dust and organic materials underscores its potential for sustainable agriculture while encouraging further investigation and development.

Theodoro and Leonard (2006) highlight that rock powders are rich sources of phosphorus, calcium, magnesium, potassium, and micronutrients. According to Conceição et al. (2022), the numerous benefits of basalt dust stem from its parent rock, which supplies essential macro- and micronutrients required for plant growth and contributes to soil pH balance. Research has indicated cost savings of up to 50% in agricultural production when basalt dust is used (Melo, Uchoa, & Dias, 2012). Many regions in Brazil have basaltic rock reserves rich in phosphorus (P), calcium (Ca), and magnesium (Mg) (Ramos et al., 2015).

An incubation study conducted with soils of contrasting textures (sandy and medium) treated with basalt dust for 90 days revealed significant improvements in soil nutrient levels. The results showed that basalt dust increased the availability of phosphorus, potassium, calcium, and magnesium by up to 20 times compared to untreated soils, due to enhanced chemical properties. Furthermore, maize and bean plants grown in basalt-enriched soils exhibited up to five times greater growth compared to plants grown without basalt dust (Conceição et al., 2022).

Similarly, other studies have demonstrated that the application of Basalt Rock Powder (BRP) significantly enhances soil chemical properties, particularly increasing concentrations of calcium, magnesium, phosphorus, and potassium (Curtis et al., 2022; Luchese et al., 2021; Marcuso et al., 2014; Martins et al., 2013).

Swoboda, Döring, and Hamer (2020) found that increased weathering of rock powders could also sequester substantial amounts of atmospheric CO2. Additionally, the silicon (Si) supplied by basalt dust can enhance plant resistance to various biotic and abiotic stresses.

However, it is crucial to consider several factors when using rock powder, as summarized in Figure 1.

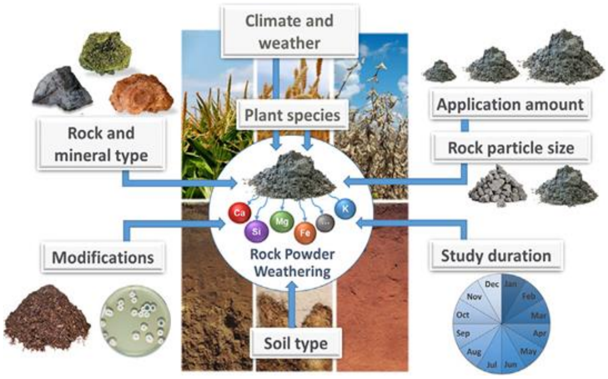

Figure 1 - The main elements to consider to use rock dust (Swoboda, Döring & Hamer, 2020)

Bergman and Holanda (2014) explains that when considering the use of a rock as a soil remineralizer, these processes must necessarily be investigated using petrography, a method that allows the recognition of minerals, their texture, order of crystallization, grain size and state of sanity. And the materials added to the soil must comply with restrictive parameters, including the content of harmful or potentially harmful elements, such as some toxic heavy metals, and components that can promote soil salinization, or add inert minerals that can compromise the soil structure. , for example, sodium compounds and quartz.

Figure 2 shows a sample of Taiano diabase, collected in the municipality of Alto Alegre- Roraima-Brazil, and with a strongly positive phosphomolybdate test.

Figure 2- Samples from Taiano diabase (municipality of Alto Alegre). Source: Brazilian geological service (2023)

In addition to Alto Alegre, occurrences of rare earth minerals, niobium, barium, and phosphate have been reported in Iracema, another municipality in Roraima. However, the exploitation of these resources is often marked by empirical practices with limited use of advanced technology. This is largely due to the fact that these soils are located within indigenous lands or rural settlements. Furthermore,

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productivity in Roraima is constrained by inadequate infrastructure, including an insufficient road network to transport inputs and outputs, a lack of skilled labor, minimal public investment, and a burdensome tax structure. Despite these challenges, Roraima's equatorial location provides climatic conditions highly favorable to agriculture (Bergmann, 2014).

Beyond the agricultural advantages of rock dust, Ramos et al. (2022) highlight its potential role in mitigating climate change through enhanced weathering. This process involves the reaction of atmospheric CO_2 with calcium (Ca) and magnesium (Mg) cations, abundant in silicate minerals like olivine, serpentine, wollastonite, and Ca-plagioclase, leading to the formation of carbonate minerals and the sequestration of CO_2. The accumulation of carbon dioxide in the soil as organic matter further contributes to reducing global warming (Boincean, 2021).

Thus, soil remineralization techniques are considered alternative routes for fertilizing soils depleted by loss of nutrients. Its importance is great in countries like Brazil, which imports around 65% of the raw materials needed to manufacture fertilizers and presents a worrying projection of demand over production in this sector, which is expected to reach 83% in 2025 (Bergmann and Holanda, 2014), as shown in figure 3.

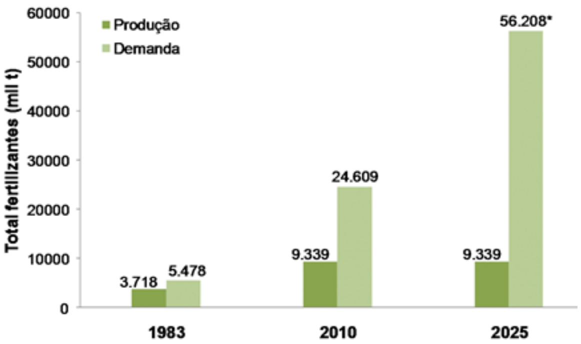

Figure 3 - Graph of fertilizer production and demand in Brazil. Adapted from Martins (2013). Source: ANDA (2011). MBAgro Projection

According to Goulart et al. (2023) the Campos Novos region, in Roraima, has magmatogenic phosphate mineralizations related to the anorthosite-mangerite-charnockite-granite (AMCG) type association, in addition to magmatichydrothermal phosphate deposits and minerals bearing rare earth elements (ETR) , linked to alkaline volcano-plutonic complexes. The gabroanorthosite units of the AMCG Mucajaí association constitute the metallotec with the greatest potential for phosphate in the region.

Target 3, located on the western edge of the Mucajaí Batholith, presented the best potential for phosphate among the targets investigated in the AMCG Mucajaí association, considering gabbroanorthositic, charnoenderbitic and granitic units (Goulart et al. 2023).

According to Bergman (2024), a sample of basic mangerito, obtained at target 3, presented a low ETR sum (600 ppm), moderate negative Eu anomaly (Eun/Eu* 0.5), low SiO2 value (48%) and high of TiO2 (2.1%), Fe2O3 (12.9%) and P (~13,000 ppm).

Due to its already established use and performance in agronomic tests, it can be stated that in Brazil, volcanic rocks with a basic composition from the Serra Geral Formation (basalts and diabases from the South, Southeast and Central-West regions) have good potential for rocking combined with the fact that they are often available as crushing fines. Although these rocks have relatively low silica contents, they have high Ca, Mg and Fe contents that are associated with mineral structures with less resistance to solubilization, with the rock being able to make them available in the short term, when added to the soil in the grain size. correct (Lefbvre et al., 2009).

In Myanmar, farming practices are tailored individually by each farmer (Siva et al., 2022). However, rock dust could be collectively adopted through agricultural cooperatives. This transition would require cultural shifts to reduce reliance on government regulations, along with training programs and financial support. The production of organic compost on farms, combined with rock powder, represents a sustainable approach, integrating mineral and organic fertilization through Knowledge Management and Organizational Intelligence practices.

Another widely recognized strategy to enhance food production is biological nitrogen fixation (BNF) in rhizobia, which typically occurs in plant roots or stems and is facilitated by bacteria in legumes. Soil microorganisms, especially those involved in BNF, play crucial roles in agroecosystems (Sa et al., 2017; Reis et al., 2020). BNF not only reduces reliance on mineral nitrogen fertilizers—which are energy-intensive to produce and transport but also limits the emission of nitrogenous gases (Reis et al., 2017; Soumare et al., 2020; Sharma et al., 2019).

The economic benefits of BNF are significant. For instance, an early U.S. study estimated that improving BNF efficiency could save $1.067 billion by reducing nitrogen fertilizer use by 1.547 million tons. Completely replacing nitrogen fertilizers with BNF could save $4.484 billion (Telles, Nogueira, & Hungary, 2023; Tauer, 1989). Globally, the economic value of BNF for legumes was estimated at $90 billion, with $8 billion attributed to the U.S. alone (Pimentel et al., 1997).

Approximately 95% of soil nitrogen exists in organic form, and only about half of these compounds have been identified. BNF converts atmospheric nitrogen (N_2) into plant-absorbable forms such as nitrate (NO_3^-) and ammonium (NH_4^+) through nitrogen-fixing bacteria, which use the enzyme nitrogenase to catalyze this process. Increased rhizobia populations in soil enhance BNF, leading to higher crop yields, improved soil fertility, and recovery of degraded areas (Embrapa, 2017).

Organic nitrogen mineralization (MNOr) is another key process, converting organic nitrogen into inorganic forms available to plants. This enzymatic process is driven by

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heterotrophic microorganisms that decompose organic matter into smaller compounds, which can then be directly absorbed or further mineralized into ammonia (NH_3) or ammonium (NH_4^+) (Vieira, 2017; Moreira & Siqueira, 2006).

Figure 4 illustrates the Nitrogen Cycle and its interactions in the soil.

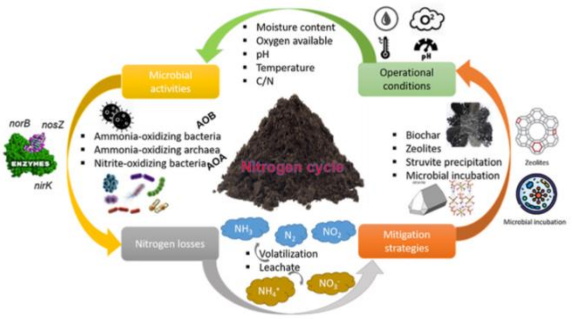

Figure 4- Nitrogen Cycle (Lindstrom and Mousavi, 2019)

Lindstrom and Mousavi (2019) emphasize that symbiotic nitrogen fixation relies on solar energy to convert inert N_2 gas into ammonia under normal temperature and pressure conditions, a process that is particularly crucial for sustainable food production in today's world.

Telles, Nogueira, and Hungary (2023) estimated the economic and environmental value of ecosystem services provided by biological nitrogen fixation (BNF) in soybean cultivation in Brazil. During the 2019–2020 harvest, BNF contributed to savings of $15.2 billion and avoided the emission of 183 million Mg CO_2-e.

Plant endophytes and rhizosphere bacteria have been shown to enhance nodule formation and improve tolerance to both biotic and abiotic stresses under controlled conditions (e.g., Eganberdieva et al., 2017). These plant growth-promoting rhizobacteria (PGPR) belong to diverse taxa and have been successfully utilized as biofertilizers in some cases. The hydrogenation of N_2-fixing root nodules can further support the activity of plant growth promoters (Schuler & Conrad, 1991).

It is worth noting that nitrogen is often supplied through green manuring practices, which include the use of plants like *Tithonia diversifolia* (Mexican sunflower). This plant can accumulate potassium (K) at rates of up to 4.3% in its leaves and stems, which can then be incorporated into compost (Palm et al., 1997, cited in Van Straaten, 2007). For these methods to succeed, integrating rock powders into the soil-plant system is crucial, as this approach supports the entire soil microbiota and accommodates the specific nutrient-extraction mechanisms of plant roots (Mundstock, 2013).

Expanding knowledge and practical experience in two key techniques—soil remineralization with rock dust and biological nitrogen fixation in rhizobia—remains essential for advancing sustainable agricultural practices.

2. Cooperatives: main basis of biodynamic agriculture

Jaeger, Harker, and Ares (2022) emphasize that biodynamic agriculture adopts an integrated approach to agriculture and food production. Biodynamic farmers embrace the holistic and spiritual aspects of biodiversity while prioritizing environmental sustainability and the well-being of their product consumers. This mature and collective practice, rooted in environmental respect, exemplifies the principles of biodynamic agriculture.

According to Silva and Salanek (2006), the social capital generated in cooperative settings enhances service provision, fosters development, improves mutual resource management, promotes education, and reduces social conflicts. Agricultural cooperatives serve as a prime example of effective cooperation and participation. Reed and Hickey (2016), referencing Bernard and Spielman (2009) and Fischer and Qaim (2012), underline the role of cooperatives in facilitating information exchange, fostering collaboration, promoting innovation, and improving market access for smallholder farmers.

Numerous studies have examined the role of agricultural cooperatives in empowering member farmers and driving agricultural development. These studies often highlight the positive impacts of cooperative practices while also addressing the challenges they face. Nasiri (2010) notes that rural populations can enhance their efficiency and economic standing through professional activities rooted in participation and cooperation. Similarly, organizing farmers into associations and cooperatives can empower them and improve their ability to implement agricultural policies (Kassie et al., 2013).

Alimohammad et al. (2022) stress that participation is the foundation of cooperative networks. They define it as a voluntary, conscious, and intentional decision-making process—whether individual or collective—that empowers participants to meet specific needs and goals. This process may occur spontaneously or through planned efforts.

However, Niyazmetov, Soliev, and Theesfeld (2021) argue that cooperatives cannot succeed without the voluntary support of small farmers. They found that the (in)compatibility of policies is often linked to asymmetries in information, low farmer trust in the state, and the limited capacity of authorities. While top-down approaches by the state may facilitate the rapid formal creation of cooperatives, such policies often lack genuine farmer engagement. Most farmers are only symbolically informed about these policies, remaining skeptical of their value and holding the state responsible for implementation. This aligns with findings by Kurakin and Visser (2017), who observed that top-down organization often discourages genuine member involvement.

To overcome these challenges, scholars advocate for changes in the institutional environment, allowing farmers more time to understand the benefits, rights, and responsibilities of cooperative membership. This is essential for them to

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internalize principles of self-organization and realize the economic advantages of cooperatives.

Many researchers agree that farmers voluntarily form cooperatives to gain proportional benefits from their participation and collaboration (e.g., Sexton, 1986; Bijman et al., 2012; Iliopoulos, 2013). The economic foundation of cooperatives lies in their ability to achieve economies of scale, mutual learning, reduced transaction costs, and the resolution of market inefficiencies (Cook, 1995; Deininger, 1995; Ortmann and King, 2007). Additionally, cooperatives—built on self-help and self-sufficiency—foster social capital and empower their members (Kotter, 1994).

Mauki, Jeckoniah, and Massawe (2023) highlight the Tanzanian government's efforts to strengthen relationships among farmers and between farmers and their land. These efforts include the provision of quality seeds, training programs, the formation of agricultural cooperatives, and facilitating the commercialization of rice (United Republic of Tanzania, 2019). Their findings reveal that UWAWAKUDA farmers achieved a profit margin of 35%, significantly higher than the general average of 24%. This success is attributed to their close collaboration with agricultural research institutes and proximity to input suppliers and traders (Mauki, Jeckoniah, and Massawe, 2023).

Mauki, Jeckoniah and Massawe (2023) show that the Tanzanian government sponsored a better relationship between farmers and between them and their land with a main focus on the donation of quality seeds, training, formation of agricultural cooperatives and facilitating the commercialization of rice [United Republic of Tanzania, 2019]

Findings show that UWAWAKUDA farmers had a profit margin (35%) higher than the general average (24%) because they worked closely with an agricultural research institute and are close to most input suppliers and traders (Mauki, Jeckoniah and Massawe, 2023).Mauki, Jeckoniah, and Massawe (2023) highlight that the Tanzanian government has fostered better relationships among farmers and between farmers and their land. This has been achieved through initiatives such as providing quality seeds, organizing training sessions, forming agricultural cooperatives, and facilitating rice commercialization (United Republic of Tanzania, 2019). Their findings show that UWAWAKUDA farmers achieved a profit margin of 35%, significantly higher than the general average of 24%. This success is attributed to their close collaboration with agricultural research institutions and proximity to input suppliers and traders.

The foundation of Inca culture exemplifies the power of cooperation and participation within agricultural communities. According to Galindo (1994), this cooperative structure was the fundamental social and economic unit that shaped Andean life. The ayllu—a community based on reciprocal relationships—enabled members to work collaboratively on communal land, ensuring subsistence and equitable redistribution of resources. Labor was organized as mutual assistance, where individual contributions were reciprocated by the community. Redistribution was systematically managed by the head of the ayllu, ensuring fair access to products while accounting for social and administrative hierarchies.

3. Integration of Knowledge Management and Government Intelligence Practices

Kanyundo, Chipetab, and Chawinga (2023) distinguish knowledge from information and intelligence. Knowledge involves contextualized information shaped by facts, perspectives, and methods, whereas information consists of organized data. Pichard et al. (2000) assert that knowledge grows through use and sharing, emphasizing that knowledge management (KM) entails discovering and fostering processes that promote collective learning.

Nonaka and Takeuchi (1995) define KM as the ability to create, share, and integrate new knowledge into products, services, and systems. Angelis (2013) elaborates that KM revolves around the interaction of tacit and explicit knowledge to enhance organizational intelligence. In higher education, KM aims to increase effectiveness, develop human resources, and expand intellectual capital (Iqbal, 2019).

Traditionally, KM practices focus on capturing knowledge, uncovering hidden repositories, and encouraging collaboration to facilitate knowledge sharing (Kamble et al., 2018). In public policy, KM can improve social participation and policy effectiveness through practices like "lessons learned" and "best practices."

Best Practices and Lessons Learned

Caruso et al. (2014) argue that "best practices" should be seen as multiple approaches rather than a single ideal solution. These practices include "promising practices," "evidence-based practices," and "science-based practices." McInerney and Koenig (2011) emphasize the importance of capturing knowledge embodied in people and making it explicit, as seen in lessons learned from past experiences. Rhem (2018) suggests categorizing lessons by type (e.g., resources, time, budget) and summarizing findings with actionable recommendations.

Communities of Practice

Communities of practice (CoPs) integrate best practices and lessons learned, forming groups of individuals united by a shared concern or passion. Wenger et al. (2002) describe CoPs as spaces for ongoing interaction, collective reflection, and knowledge sharing. Souza-Sila and Davel (2007) highlight that CoPs expand learning and social competence through dialogue and mutual reflection.

Storey (2004) notes that CoPs function as self-organizing systems, where members must demonstrate competence to contribute meaningfully. Wenger (2000) further describes these communities as self-sustaining ecosystems of knowledge generation, fostering collective expertise and innovation.

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Communities of Practice (CoPs): Key Elements

A Community of Practice (CoP) is defined by three essential elements: **domain**, **community**, and **practice**:

1. **Domain**: A CoP derives its identity from a shared area of interest. Members are committed to this domain, bringing diverse perspectives and intelligences to collaboratively learn, grow, and excel. Their contributions are valued for advancing collective expertise, distinguishing CoPs from informal social groups found on networks.
2. **Community**: Participation involves active engagement in discussions, collaboration on projects, and addressing shared challenges. CoPs foster relationships that enable learning, even among individuals who may not have previously interacted. Members help one another and exchange information driven by their mutual interest in the topic.
3. **Practice**: Members of a CoP engage in a shared practice, exchanging experiences and knowledge to advance their expertise (Wenger, 2006).

Suggested Communities of Practice for Social Participation

1. **Tools for Social Participation**: Exploring best practices and lessons learned from federal government initiatives.
2. **Best Practices in Brazilian States**: Sharing successful examples of social participation at the state level.
3. **Indicators of Social Programs**: Developing and analyzing existing and proposed social program indicators.
4. **Brazil-Argentina Social Programs Comparison**: Examining programs and partnerships between the two countries.

Organizational Intelligence (OI) and Knowledge Management (KM)

Organizational Intelligence (OI) emphasizes leveraging the quality and characteristics of business knowledge to innovate and improve decision-making (Rezaei et al., 2012). Erickson and Rotherberg (2004) describe intelligence as knowledge applied to specific situations. Harold Wilensky first introduced OI in 1967, highlighting its impact on organizational efficiency and effectiveness.

Knowledge Management (KM) complements OI by focusing on the creation and sharing of knowledge, while OI interprets and applies this knowledge for problem-solving and decision-making.

Selected OI Practice: Expert Analysis

The chosen OI practice for this initiative is **expert analysis**, where each CoP will have a leader responsible for:

- Motivating and facilitating group activities.
- Analyzing and synthesizing knowledge.
- Delivering actionable insights to decision-makers.

Balancing **knowledge creation** (KM) and **knowledge application** (OI), supported by favorable conditions within CoPs, is critical. This approach lays the foundation for effective **shared governance**, the subject of the next section.

4. The Culture, Knowledge, and Intelligence Model (CKI)

Roland (2000) provided practical insights into the formation of cultures and their relationship to knowledge and intelligence. The anthropological definition of culture, introduced by Edward Tylor in *Primitive Culture* (1871), suggests that culture is a natural phenomenon with causes and regularities that can be studied systematically.

Kroeber (1949) expanded on this by stating that humans differ from animals through culture, which accumulates through learning and experience. This idea aligns with Sen's (2000) view of education as freedom, as cultural elements—beliefs, values, assumptions, and traditions—are integral to fostering collaboration and participatory initiatives, such as agricultural cooperatives.

Schein (2010) defines culture as the interplay of beliefs, values, assumptions, and traditions, reinforced by underlying assumptions. Changing culture is challenging because these elements are deeply embedded, but influencing cultural assumptions, such as artifacts and symbols, can shape organizational climate and teamwork.

Espinoza-Santeli and Jiménez Vera (2028) argue that managing organizational climate (OC) requires a commitment to improving the quality of life for members of an organization, ultimately creating an environment conducive to successful collaboration and innovation.

The Student's T-test for the Pearson correlation coefficient is a statistical tool used to assess whether a relationship exists between two variables, or whether they are independent, by making inferences about their relationship or lack thereof.

Umuteme and Adegbite (2023) discovered a correlation between Organizational Culture and Leadership, with Pearson's correlation coefficient (R) equal to 0.48 and a T-statistic of 7.93. They argue that organizational culture has a strong influence on team effectiveness, creating an environment where team members can exchange knowledge and experiences with leadership. This perspective aligns with the work of Alvesson (2002), who emphasized that focusing on organizational culture can lead to multiple advantages for projects. A strong, well-defined culture fosters a sense of unity and shared purpose among team members. When employees are aligned with the organization's values, mission, vision, and goals, they are more likely to collaborate and work harmoniously toward the project's success.

The key is to develop an environment and culture where employees prioritize collective goals over individual gains such as rewards, benefits, or higher positions. This fosters cooperation and teamwork, facilitating the smoother design, execution, and review of projects.

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Kroeber (as cited in Félix Keesing) suggests that culture is a cumulative process, shaped by the historical experiences of past generations. This cultural accumulation limits or stimulates individual creativity. Kroeber and Keesing also argue that there is no direct correlation between genetics and culture, as individuals, regardless of their birthplace, absorb the culture of the environment in which they are raised. Kroeber further asserts that humanity's distinction from animals is attributed to culture—through culture, humans transcend their biological limitations and accumulate knowledge and experiences over time.

According to Kroeber, the key points regarding culture are:

1. Culture, more than genetics, determines behavior and influences individual actions.
2. People age according to cultural standards, as instincts are less influential due to the long "evolutionary process" of culture.
3. Culture is a cumulative process that builds upon the historical experiences of past generations, shaping or limiting individual creative actions.

Hofstede (2011) emphasizes that culture plays a pivotal role in shaping individuals' minds, establishing shared values specific to the members of a group. Empirical research consistently supports the idea that culture positively influences cognitive processes and psychological reasoning (Shiraev & Levy, 2010). Cultural influences significantly impact how individuals think and make decisions, underlining the importance of culture in cognitive development.

Building on these theoretical foundations, the Culture-Knowledge-Intelligence (CCI) model is introduced, as illustrated in Figure 5.

The key premises of the CCI model include: (i) Culture is formed by the beliefs, values, assumptions, and traditions of a society (Schein, 1985). (ii) The central premise of the model is that for education to succeed in its objectives, the curriculum must be restructured or reformulated based on the four pillars of learning: learning to know, learning to do, learning to live together, and learning to be (Nan-Zhao, 2000). (iii) The three pillars of intelligence are: prediction, strategy and action (Rothberg and Erickson, 2004)

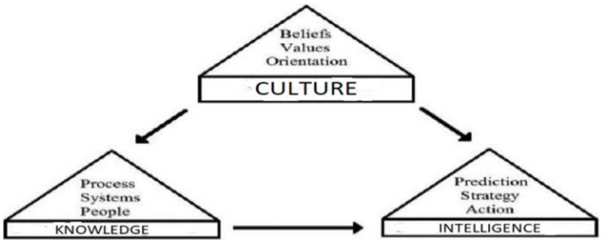

Figure 5- CULTURE-KNOWLEDGE-INTELLIGENCE MODEL (adapted from Choo, 1998)

The CCI model is based on three hypotheses (Table I):

Table I. Assumptions of the CCI model

Hypotheses	Sources	Results
Cultural has a positive impact on Knowledge	Umuteme and Adegbite (2023) define culture from the perspective of learned beliefs and values, which reinforce behavior both personally and as a group, or society, nation.	SUPPORTED
Cultural has a positive impact on intelligence	Culture, more than genetics, determines behavior and determines its actions (Kroeber, 1949).	SUPPORTED
Knowledge has a positive impact on intelligence	Rothberg and Erickson (2004) maintain that intelligence is knowledge in action.	SUPPORTED

5. BIODYNAMIC AGRICULTURE MODEL BASED ON INCA CULTURE

According to Veiga (2022), smart cities emerged mainly as a result of Information, Communication Technologies (ICT), but without the concern of creating conditions and a culture that promote entrepreneurship through a more decentralized and anthropocentric approach and in ways that promote collaboration and community participation. interested, in order to improve understanding and address the complementarity of political-institutional, economic-business-environmental aspects and mainly the sociocultural aspect, such as citizens' commitment.

Research Methodology

The study uses the literature review methodology in an integrated way to better understand the impact of culture on knowledge and intelligence.

Snyder (2019) states that literature review as a research method is more relevant than ever. Traditional literature reviews present a careful menu of thoroughness and rigor and are carried out on an ad hoc basis rather than following a specific methodology.

In the article, it will be argued that the potential for theoretical and practical contributions using the literature review as a method will be advanced to clarify what a literature review is, how you can use it, and what criteria should be used to assess its quality.

This article carries out an integrated review of the literature on Inca culture, rock dust, biological nitrogen fixation, agricultural cooperatives, culture, knowledge and intelligence.

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Integration occurs not only in the literature review itself, as the intersection between these concepts is demonstrated through different sources, but also through the research model in which the constructs are present.

Figure 6 shows the biodynamic family farming model.

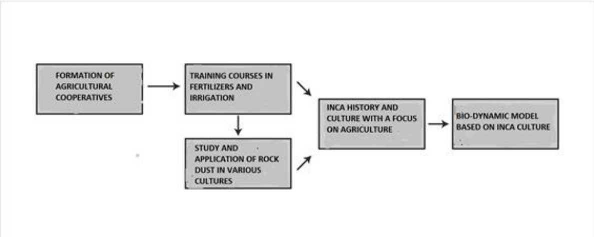

Figure 6 - Biodynamic family farming model

Fuente: Authors, 2023

This biodynamic agriculture model shows that the basis for this type of agriculture is agricultural cooperatives. However, for farmers to be willing to come together to solve their problems, there is a need for an appropriate culture that accepts training courses, particularly on the topics of fertilizers and irrigation, two topics covered in the previous sections. Therefore, both training courses, particularly on rock powder, and Inca history and culture are also good foundations for the development and maintenance of biodynamic agriculture.

Recommendations for future study

In a future study, the researcher could conduct a study in a rural area of Peru to observe and demonstrate, once again, that the government has difficulty reaching low-income farmers because it is unable to establish field teams to visit them. The isolation between geographically isolated urban and rural areas should be the main reason for the creation of a financial and educational support plan for agriculture and that is why surveys of farmers using the AGRIS methodology (in English, Agricultural Integrated Survey Program) are necessary.), which is a global Strategy through a Global Workshop for improving agricultural and rural statistics created by a group of researchers led by Prof. FRANÇOIS FONTENEAU, and is related to IDA – International Development Association.

AGRIS has five Modules: Economy, Labor, Production Methods and Environment, Machines, Equipment and Assets. The issues are: -Financing of production, Demographic and educational profile, Agricultural infrastructure (transport, communication and access to community facilities and resources), Climate change mitigation strategies. Crop Rotation, Sales Prices. Sources of Energy, Conducting Soil Analysis, Poisons, Fertilizers, Seeds, Irrigation Methods and Water Regimes during the growing season and Source of Farmer Information.

CONCLUSIONS

The objectives of this study were: i) to propose a model that captures the relationship between culture, knowledge, and intelligence, and ii) to develop a biodynamic agriculture model influenced by Inca culture. The Culture and Knowledge-Based Intelligence (CKI) model offers a conceptual framework for the formation and development of agricultural cooperatives, with a particular emphasis on non-chemical fertilizers, such as rock dust.

This study highlights that intelligence, which involves the application of knowledge, is more critical than knowledge itself when it comes to driving development. Consequently, barriers to accessing relevant knowledge and its practical application among farmers can be overcome through the creation and development of cooperatives that facilitate knowledge sharing, mutual growth, and the exchange of experiences.

Previous research has shown that university-industry collaboration is an effective method for business training, as it blends academic theory with practical experience. However, challenges remain in industries accessing academic knowledge and farmers acquiring both theoretical and hands-on experience.

The authors suggest that further research be conducted on a larger scale to gain a deeper understanding of the interactions between the variables in the CKI model and the biodynamic agriculture model. Special attention should be given to the relationship between culture and knowledge in enhancing intelligence and to the cultural influences of Inca traditions on the adoption of biodynamic agriculture methods. This includes the use of rock dust and nitrogen fixation to reduce dependence on harmful chemical fertilizers, which negatively impact soil quality.

References

1. Alimohammad , M. Hosseini, S. J. F. Mirdamadi, S. M. 2023. Collaborative networking among agricultural production cooperatives in Iran. Heliyon Journal
2. Anang, B.T., & Asante, B.O. Farm household access to agricultural services in northern Ghana. Heliyon, 6.
3. Asseng, S., Ewert, F., Martre, P., Rötter, R.P., Lobell, D.B., and Cammarano, D. (2015) Rising temperatures reduce global wheat production. Nat. Clim. Change 5: 143– 147.
4. Bergmann, M. Holanda, J.L.R (2014). Rochagem. In: GEODIVERSIDADE DO ESTADO DE RORAIMA: PROGRAMA GEOLOGIA DO BRASIL. ISBN 978-85-7499-162-7
5. Bertolozzi-Caredio, D., Bardají, I., Coopmans, I., Soriano, B., & Garrido, A. (2020). Key steps and dynamics of family farm succession in marginal extensive livestock farming. Journal of Rural Studies, 76, 131-141.
6. Flores Galindo, A. Buscando Un Inca. Identidad Y Utopía En Los Andes [ocr] [1994]
7. Grubbström et al. (2012). Estonian family farms in transition: a study of intangible assets and gender issues in generational succession J. Hist. Geogr.
8. Hansen B. D., Leonard E., Mitchell M. C., Easton J., Shariati N., Mortlock M. Y., Schaefer M., Lamb

*Corresponding Author: **Cristiano De Angelis.**

D. W. (2022). Current status of and future opportunities for digital agriculture in Australia. Crop & Pasture Science.

9. Jaeger, S. R. Harker, F. R., Ares, G. 2022. Consumer perception of the contributions of biodynamic agriculture to sustainability and biodiversity conservation: Insights from the United Kingdom, Australia, Singapore and Germany. Science talks Journal.
10. Junquera V., Rubenstein D.I., Grêt-Regamey A. & F. Knaus. (2022). Structural change in agriculture and farmers' social contacts: Insights from a Swiss mountain region. Agricultural Systems.
11. Lefebvre, D. Pietro Goglio, Adrian Williams, David A.C. Manning, Antonio Carlos de Azevedo, Magda Bergmann, Jeroen Meersmans, Pete Smith (2019). Assessing the potential of soil carbonation and enhanced weathering through Life Cycle Assessment: A case study for Sao Paulo State, Brazil, Journal of Cleaner Production, Volume 233,
12. López, Carlos y Aguilar, Julia (2015, 15 de noviembre). Logros de la economía en la Epoca Pre Inca. Historia del Perú. https://historiaperuana.pe/periodo-autoctono/logros-economia-epoca-pre-inca
13. Mazhar, Fauzia & Jam, Farooq & Anwar, Farooq. (2021). ZINC-ASPARTATE-MEDIATED DROUGHT AMELIORATION IN MAIZE PROMISES BETTER GROWTH AND AGRONOMIC PARAMETERS THAN ZINC SULFATE AND L-ASPARTATE. SABRAO Journal of Breeding and Genetics 53 (2) 290-310. Available at http://sabraojournal.org/wp-content/uploads/2021/06/SABRAO-J-BREED-Genet-53-2-290-310-Mazhar.pdf
14. Mauki, C. Jeckhoniah, J. Massawe, G.D. 2022. Smallholder rice farmers profitability in Agricultural Marketing Co-operative Societies in Tanzania: A case of Mvomero and Mbarali districts. Heliyon Journal
15. McNamara, C. (1999). General Guidelines for Conducting Interviews, Minnesota.
16. Miller J, Glassner B. (2004).'The "inside" and the "outside": finding realities in interviews, in D Silverman (ed.), Qualitative research: theory, method and practice, 2nd, Sage, London pp. 125-39.Independence.
17. Morseletto, P. (2019). Confronting the nitrogen challenge: Options for governance and target setting. Global Environmental Change.
18. Niyazmetov, D. Soliev, I. Theesfeld. 2021. Ordered to volunteer? Institutional compatibility assessment of establishing agricultural cooperatives in Uzbekistan. Land Use Policy Journal.
19. Nyantakyi-Frimpong, Hanson and Rachel Bezner-Kerr. (2015). "The relative importance of climate change in the context of multiple stressors in semi-arid Ghana." Global Environmental Change-human and Policy Dimensions 32 : 40-56.
20. Paull, John. (2011). Attending the First Organic Agriculture Course: Rudolf Steiner's Agriculture Course at Koberwitz. European Journal of Social Sciences – Volume Number. 21.
21. Raupp, Joachim. (2001). Manure Fertilization for Soil Organic Matter Maintenance and its Effects Upon Crops and the Environment, Evaluated in a Long-term Trial.
22. Ray DK, West PC, Clark M, Gerber JS, Prishchepov AV, Chatterjee S. (2015). Climate change has likely already affected global food production. PLoS One. 31;14(5):e0217148.
23. Kumawat, K. C., ,Razdan, N., Saharan, K. 2022. Rhizospheric microbiome: Bio-based emerging strategies for sustainable agriculture development and future perspectives. Micro Biological research 2022
24. Rosenzweig, C., Jones, J.W., Hatfield, J.L., Ruane, A.C., Boote, K.J., Thorburn, P., Antle, J.M. (2013). The Agricultural Model Intercomparison and Improvement Project (AgMIP): Protocols and pilot studies,Agricultural and Forest Meteorology,Volume 170.
25. (2006). . Capital Social e Cooperativismo no processo de desenvolvimento sustentável: estudo da cooperativa Bom Jesus - Lapa/ PR. In: Gilson Batista de Oliveira; José Edmilson de Souza-Lima. (Org.). O desenvolvimento sustentável em foco: uma contribuição multidisciplinar. São Paulo: ANNABLUME. v.
26. Andrea Saltelli, A. Kuc-Czarnecka, M. Lo Piano, S. Lorincz, M. Olczyk, M. Puy, A. Reinertf, E. Smith, S. Sluijs, J. (2023) Impact assessment culture in the European Union. Time for something new?. Environmental Science and Policy Journal.
27. Schein, Edgar H. (1985). Organizational Culture and Leadership. San Francisco: Jossey-Bass Publishers.
28. Steinfeld, H. ; Gerber, P. ; Wassenaar, T. ; Castel, V. ; Rosales, M. ; de Haan, C., 2006. Livestock's long shadow,. FAO, Rome.
29. Stiglbauer, A.M. and Weiss, C.R. (2000). Family and Non-Family Succession in the UpperAustrian Farm Sector, in: Cahiers d´économie et sociologie rurales, 2000.
30. URT (United Republic of Tanzania), Ministry of Agriculture, National Rice Development Strategy Phase II 2019-2030, 2019. Dar es Salaam, Tanzania. 48pp.

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