Agroecological alternatives for crop management without use of highly hazardous pesticides in Costa Rica

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Agroecological Alternatives for Crop Management Without Use of Highly Hazardous Pesticides in Costa Rica

Summary

The "Los Sukias" farm, located in Bebedero, Cañas, Guanacaste, has established itself as a benchmark for large-scale organic agricultural production. With clay and sandy loam soils and access to flood irrigation from the Bebedero River, it primarily grows rice (*Oryza sativa L.*) and sugarcane (*Saccharum officinarum L.*). Since 2012, it has transitioned from a conventional model to a regenerative system, completely eliminating the use of agrochemicals and adopting certified agroecological practices under the "EcoArroz" brand. Minimum tillage, crop rotation, mulch, bioinputs, and integrated pest management are pillars of the production model, which improves soil quality and strengthens biodiversity.

The benefits of this type of production system are tangible: yields close to eight tons per hectare, reduced production costs compared to conventional agriculture, and higher prices due to its value as an organic product. This has positioned Los Sukias in differentiated markets. Beyond productivity, the model also provides environmental and social benefits: carbon capture, emissions reduction, water retention, and flora and fauna conservation, among others. The Los Sukias experience demonstrates the viability of producing food sustainably, profitably, and ethically, constituting a replicable model that positions agroecology as a climate solution, a real alternative for agricultural production in Costa Rica and a source of inspiration nationwide.

Farm owner: Andrés Vázquez Ulate

Location: The farm is located in the Bebedero district, Cañas canton, Guanacaste province, Costa Rica, at an altitude of 15 to 20 meters above sea level. It is a seasonally wet and dry area, with a rainy season from May to November and a dry season from December to April, but with access to irrigation water.

Productive area of the property: The farm currently has 216 hectares of agricultural area, of which approximately 84 hectares are cultivated with certified organic rice, 5 hectares of organic sweet potatoes, and another 127 hectares are leased to produce organic sugarcane. The remainder is forested, buffer zones, roads, and houses. The sugarcane area is currently managed by Ingenio El Viejo, as the milling process must be separate from the conventional process. El Viejo also has more than 2,400 hectares of certified organic sugarcane. Rice has been grown on leased plots for more than 25 years, 47 hectares on land leased from Aquacorporación and 37 hectares in Paso Lajas, all certified organic.

Background

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Aerial view of Los Sukias farm.

Photo credits: Andrés Vasquez

Background (cont.)

In the Bebedero region of Cañas, Guanacaste, on the plains of the Bebedero River, the Los Sukias farm developed a conventional agricultural production model for years, primarily focused on intensive rice planting since 1983. In 1999, the farm covered 163 hectares and was dedicated to the cultivation of sugarcane, rice, and livestock. One of the main problems facing rice cultivation at that time was, among many others, the control of weedy rice. In response to this and other problems, and within the framework of a research project documented by the Costa Rica Institute of Technology (TEC, by its acronym in Spanish), an integrated management system was implemented that combined various chemical, physical, mechanical, and cultural strategies from 1999 to 2006. The results were significant: the contaminated rice seed bank was reduced, and crop yield increased from 4.6 tons per hectare in 1999 to more than 7 tons per hectare in 2006. However, over time, the farm's production vision evolved.

Around 2012, Los Sukias decided to make a significant shift toward a more sustainable and environmentally friendly model. It was then that they began replacing or significantly reducing the use of synthetic insecticides and fungicides, instead incorporating biological products, as well as inoculating fungi and bacteria or biocontrol agents. This paradigm shift was key to positioning their rice as "EcoRice." This transformation process not only involved a technical change in agricultural practices but also a conceptual evolution in farm management, incorporating principles of agroecology and integrated management that now constitute the core of its production model. The Los Sukias farm represents an example of sustainable agricultural management. The implementation of agroecological practices has led to improvements in productivity and sustainability. This approach constitutes a viable alternative for rice-producing areas in Costa Rica and provides solid evidence of the effectiveness of integrated management in pesticide-free production contexts, strengthening Los Sukias's position in agricultural innovation.

Physical & Social Characteristics of the Farm

Crops: The farm is primarily dedicated to the organic production of sugarcane and rice, integrating different techniques that allow for large-scale production while reducing environmental impact and the use of chemical inputs. Lettuce, chili, basil, sweet potatoes, and tomatoes are also grown on a small scale.
Legal relationship to the land: Owner, with right to use for food production, service providers are also subcontracted. The farm has no donors.
Number of workers: Approximately eight workers
Soil type: The majority of the farm's soil is clay soil, with access to flood irrigation; another portion is sandy loam and well-drained.
Access to irrigation water (rivers, lakes, others): The farm's water source comes largely from the Bebedero River and the irrigation canals of the National Irrigation and Drainage Service (SENARA, by its acronym in Spanish).
Biome: In Guanacaste, the original biome is the tropical dry forest, composed of predominantly vertisol soils. It features deciduous trees adapted to long periods of drought. Much of the ecosystem has been replaced by intensive agricultural systems, predominantly pastures for livestock and crops such as rice, sugarcane, melon, among others.
Climate of the area (temperatures, precipitation, etc.): The area has maximum temperatures of 32.96°C, minimum temperatures of 23.75°C, and an average of 28.35°C, located in latitude 10 39109 and longitude 085 18060; with an average annual rainfall of 1691 mm.

Crotalaria is a cover crop that improves soil fertility, structure, physical, chemical and biological properties, and it is a weed control crop.

Agroecological practices

The Los Sukias farm employs a regenerative production model based on soil conservation and the use of bio-inputs. Practices include minimum tillage, incorporation of crop residues, planting cover crops such as *Mucuna* sp. and *Crotalaria* sp., and water management through temporary flooding to control weeds and pests. These techniques improve soil structure, promote biodiversity, encourage microbial activity, and reduce the use of agrochemicals. In addition, rice is established by mechanical transplanting with pre-germinated seeds to achieve rapid crop closure and less competition with weeds.

The system's management is complemented by the internal production of biofertilizers (such as worm tea, bone meal, and enriched compost), biodigesters that generate liquid fertilizer and biogas, and biological and manual pest control practices. The wild species and animals present on the farm fulfill ecological functions, providing natural fertilization, insect control, and pollinator attraction. This approach makes it possible to maintain competitive yields at low costs, improve the health of the agroecosystem, and consolidate a sustainable and self-sufficient agricultural system, reducing the need for chemical inputs and strengthening the crop's resilience to biotic and abiotic factors.

Diversified cropping system

System diversification combines the use of cover crops, wild plants, living barriers, or intercropping to improve soil health by increasing organic matter input, promoting biological nitrogen fixation, and stimulating microbial activity. Furthermore, by maintaining a greater variety of plants, habitats are created for pollinators and beneficial organisms that contribute to the ecological balance of the agroecosystem. In this way, the functional diversity of the system helps to naturally regulate pest and disease populations.

The system includes rice planting between November and December (waiting for the months of greatest sunlight) by mechanical transplanting, using pre-germinated seed at a high density (150 kg/ha), which promotes rapid crop closure and reduces weed competition. Harvesting takes place between March and April, months of the dry season that allow for less crop damage. After harvest, the fields are managed with mulches such as crushed dry rice tissue. The rice plants resprout and remain in the field for three months for a second harvest. Later, in August or September, *Crotalaria* sp. (or *Mucuna* sp.) is sown in the soil at a density of 20 kg/ha of seeds as a living mulch/cover crop that fixes 120 kg/ha of nitrogen. After 3 months, the cover crop is incorporated into the soil to provide organic matter. The edges of the crop, irrigation canals, and surrounding areas are maintained with vegetation of wild plants throughout the rice growing cycle.

Adoption & Assimilation

Agroecological methods have been consistently implemented, making the farm a national benchmark for responsible production. For his contributions to the agricultural sector, Vásquez received the Medal of Agricultural Merit in 2016. In areas of Guanacaste, local media such as "Guanacaste a la Altura" have highlighted his commitment and leadership to sustainable farming, helping to spread regenerative practices in the region.

Benefits

Climate Change Mitigation

- The regenerative organic system avoids the intensive use of synthetic fertilizers and pesticides, reducing the carbon footprint associated with the production and distribution of agrochemicals and other fossil-fuel intensive methods of agricultural production.
- Living barriers, walls, and vegetated slopes, as well as permanent mulch with species such as *Mucuna* sp. and *Crotalaria* sp., contribute to soil carbon sequestration. Based on the farm's experience, a recovery of organic matter and fertility is observed, which increases the capacity to retain carbon.

Climate Adaptation

- Vegetation cover management and crop rotation improve soil structure, providing water retention capacity during dry periods or heavy rainfall.
- Trees as living fences reduce wind speeds, water runoff, and extreme temperatures.

Biodiversity

- Conservation of wild plants on edges and borders, the use of living barriers, and cover crops promote the presence of pollinators and beneficial insects (ladybugs, dragonflies, spiders, centipedes, millipedes, etc.)
- Biodiversity within the system creates refuge and food spaces for animals such as birds, toads, frogs, and visits from coyotes

Economics

Rice production costs range between US$2,350 and US$2,550/ha, and a sack of rice sells for around US$60 because it is organic. In contrast, conventional rice production costs between US$11,765 and US$13,725/ha (five times higher), and the selling price is US$28.40 (half the price of organic rice). Some production costs for organic rice farming are listed in Table 1.

Table 1. Costs indicated by the farmer in the management of organic rice.

Item	Costs in US dollar/ ha
Leachate	$ 0.20
Bamboosine and melaza	$ 1.18
Bone bio-ferment	$ 1.37
Worm tea-type bioferment	$ 2.60
Manual weed control	$ 68.63
Ash-enriched compost (production)	$ 176.47
Ash-enriched compost (production) in batches with Mucuna sp.	$ 47.06

It should be noted that ash-enriched compost has an approximate production cost of US$1.20 per 45-kilogram bag. In productive management, approximately 150 bags are applied per hectare, for a total cost of US$470.60 (considering both production and application). Comparatively, in conventional systems, the main source of nitrogen is urea, which requires 16 bags per hectare, reaching an approximate cost of US$588, which represents a 20% increase. As mentioned, in regenerative plots with Mucuna sp., only 40 bags/ha are applied. The rice produced by Andrés has been managed through local cooperative/industrial chains, and there is institutional interest from the Ministry of Economy, Industry, and Commerce (MEIC, by its acronym in Spanish) and the Ministry of Agriculture and Livestock (MAG, by its acronym in Spanish), in conjunction with the Development Banking System (SBD, by its acronym in Spanish), to promote this type of production.

Benefits (cont.)

Economics (continued)

In Costa Rica, the chemical inputs used in conventional rice production vary in price and application rates. Herbicides include 25% quinclorac, applied at a rate of 1.4 L/ha, and 50% pendimethalin, used at 3 L/ha. Insecticides include 60% diazinon at a rate of 1.6 kg/ha, while 25% cypermethrin at 0.2 L/ha. Fungicides include 50% carbendazine at 0.6 L/ha and 43.5% mancozeb at 4 L/ha, among others. In total, pesticides, synthetic chemicals and other components represent an elevated cost (US$11,765 and US$13,725, mentioned above) in conventional rice cultivation systems. According to a CONARROZ report for the 2022-2023 period, Costa Rica's rice production systems (mostly conventional) achieved average yields of approximately 4.24 tons per hectare, a figure far from the 7 to 8 tons yield achieved by Vázquez.

Socio-environmental health

- Workers, consumers, and families are not exposed to toxic molecules thanks to organic and sustainable production (reducing the risk of poisoning).
- The total elimination of synthetic pesticides prevents the contamination of irrigation canals and water sources, benefiting both aquatic fauna and surrounding communities, wetlands of Ramsar importance, and national parks.
- High production of organic rice, one of society's most consumed crops historically and globally.
- Organic agriculture represents a more sustainable model that protects the environment and prevents long-term damage associated with the use of agrochemicals.

Gender & Gender Equality

The family participates in rice and sugarcane production; the wife is responsible for general management and part of the laboratory for the production of *Trichoderma* spp. (beneficial fungus that reduces disease in plants) and other biological control agents.

Community Organization

The experience of the Los Sukias farm has served as a demonstration space for neighboring producers, students, and professionals, promoting the exchange of knowledge. They receive frequent visits from students from agricultural colleges and universities, producer groups, professional associations, and those interested in agroecology.

Achievements

Andrés Vásquez's work has been officially recognized with the 2016 National Medal of Agricultural Merit, awarded by the Ministry of Agriculture and Livestock and the Presidency of the Republic of Costa Rica. This award recognized his career, innovation, and commitment to sustainable production, especially in reducing the use of agrochemicals.

The practices implemented on the farm have generated concrete results, including yield increases and a strong positioning of the product in markets that value safety and sustainability, as reflected in its acceptance by Coope Liberia under the Sabanero brand.

Vásquez has taken an active role in international education and the transfer of agroecological knowledge, participating in conferences and training sessions in countries such as Colombia and Venezuela, sharing his experiences and promoting the adoption of sustainable agricultural practices.

Lessons learned

- Experience shows that agroecological systems are not exclusive to small gardens or experimental plots. On large farms, such as Los Sukias, it is evident that it is feasible to maintain competitive yields without the need for pesticides.
- Many producers in Costa Rica still perceive conventional agriculture as the only profitable way to produce. This cultural and commercial bias makes it difficult to adopt sustainable ecological models.
- It is possible to produce food profitably without compromising the health of the soil, water, biodiversity, and people.
- The agroecological transition requires experimentation, and not all producers are comfortable taking on the uncertainty of changing a system they have managed for years regardless of its sustainability

Recommendations

Learning & Collaboration

- Explore organic production through experimentation with demonstration plots, where each producer can observe real results under local conditions.
- Establish horizontal learning and exchange networks between farmers who already apply organic practices and those beginning their transition.

Policies

- Join forces between institutions, organizations, and farmers, creating permanent spaces for dialogue and knowledge transfer, to encourage the adoption of sustainable agricultural practices.
- Promote environmental education from school to university, strengthening social awareness about sustainable food.
- Establish an inter-ministerial approach that articulates coordination between the Ministry of Health, the Ministry of Agriculture and Livestock (MAG, by its acronym in Spanish), the Ministry of Environment and Energy (MINAE, by its acronym in Spanish), National Groundwater, Irrigation and Drainage Service (SENARA, by its acronym in Spanish) and the Ministry of Public Education (MEP, by its acronym in Spanish) of Costa Rica, with the aim of designing and implementing actions focused on climate change mitigation, resilience, and adaptation.

Environmental

- Promote ecological restoration in degraded areas with native species for ecological succession and agroforestry/silviculture.
- Promote circular production by leveraging agricultural and organic waste to generate energy and fertilizers, as well as the integration of animals for a more diverse and dynamic system.

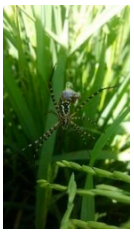
Ethics & Morality

- Promote a holistic view of ecology, where humans are caretakers, not exploiters, of natural resources.
- Promote a pro-life production model, where production is not measured solely by economic returns, but by the ability to regenerate soils, nourish communities, and coexist with the environment.

Appendix 1: Agroecological practices implemented at the Sukias farm

Practice	General information	Agroecology principles
Soil tillage method	Minimum tillage with incorporation of rice straw; wetting and passing a surface harrow (3–5 cm) to diminish erosion and improve soil health.	Soil health, nutrient recycling, soil erosion reduction.
Soil conservation	Use of *Mucuna* sp. as green manure and natural control of weeds. Soil flooding for 1–2 months to induce anoxia and eliminate pest larvae (*Phyllophaga* spp.). Presence of birds that contribute 15–30 t/ha of manure. Use of *Crotalaria* sp. to fix nitrogen and biologically restore the soil. Vegetation in canals, field edges, living barriers, etc.	Synergy, system diversification, nutrient recycling, improvement of the soil's physical, chemical, and biological properties
Types of biofertilizers	Production of 5,000 L/month of bio-ferments. Production of worm tea, bone meal bio-ferment, compost with ash, and fishmeal. Dosage: 25–30 kg/ha (worm tea), 5 L/ha (bone meal). Compost provides 25–50 kg N/ha; use reduced to 40 bags/ha in regenerative areas. Biodigester that produces 40–60 L/day of liquid fertilizer and 4–5 hours of biogas. The rice fields are inoculated with *Azolla*, a plant formed by the symbiotic interaction between a fern and the alga *Anabaena azollae,* which fixes atmospheric nitrogen.	Soil structure improvement, biodiversity conservation, soil microbiology
Origin and sowing of seeds/seedlings/plants	FLAR varieties (select seeds). Mechanical sowing with pre-germinated seed (150 kg/ha). Harvest March–April. Covering with *Crotalaria* sp. or *Mucuna* sp. (20 kg/ha) that fixes 120 kg N/ha.	Biomass recycling, reduced soil erosion, fertility, diversification
Pest and Disease Management Practices	Manual and mechanical weed control (*Echinochloa* spp., *Aeschynomene* spp.). Use of bioferments and pyroligneous acid for pest and disease management. Light traps with soapy water for lepidopteran and coleopteran pests. Shelter for beneficial insects (ladybugs, dragonflies, spiders). Natural control of *Phyllophaga* spp. by centipedes and millipedes. Birds, frogs, and toads contribute to control.	Biological pest control, increased functional biodiversity, reduced chemical inputs, and increased resilience of the production system
Use of wild plants	Living barriers with trees, palms and spontaneous vegetation (*Tridax procumbens, Euphorbia prostrata*, cucurbits) for biological control and attraction of pollinators.	Diversity, ecosystem services, habitat conservation, attraction of beneficial organisms and pollinators
Animals	The farm has its own chickens, and is also visited by various wild species, such as herons, ducks, and coyotes, which come from the surrounding natural ecosystem.	Ecological balance, animal-plant interaction, nutrient recycling

Appendix 2: Components in Las Suskias agroecological production system
Photo credit: Andrés Vázquez

Component	Contribution in an agroecological cropping system.	Photograph
Wild flowers	They promote biodiversity by attracting pollinators and natural enemies of pests, contributing to the ecological balance of the system.	
Dragon flies	They act as natural predators of insect pests, especially small insects of the order Diptera, contributing to biological control in rice crops.	
Ladybugs	They are effective biological controllers, as they feed on aphids, mites, and other phytophagous insects that consume rice crops.	
Spiders	They contribute to biological pest control by capturing a wide variety of insects (lepidoptera, coleoptera, diptera, etc.) at all stages of the crop.	 
Frogs	They regulate insect and other invertebrate populations, in addition to being an indicator of environmental quality and low chemical pollution.	
Birds	Consuming weed seeds, insects, snails and other organisms considered pests such as small rodents that consume rice grains.	
Organic rice with living fences and trees in the boundaries	They provide shade, reduce wind erosion, enhance biodiversity, and provide shelter and food for birds and beneficial insects. They also contribute to carbon sequestration and microclimate regulation.	

Component	Contribution in an agroecological cropping system.	Photograph
Organic fertilizer spraying	It improves soil structure and fertility, increases moisture retention and promotes microbial activity.	
Biodigestor	It allows the use of organic resources to generate biogas and biofertilizer, reducing costs and polluting emissions.	
Mucuna sp. controlling weeds	It acts as a cover crop, green manure, and nitrogen fixer, improving soil fertility, structure, and physical, chemical, and biological properties, as well as controlling weeds through mulching.	
Crotalaria sp. as a cover crop	Like *Mucuna* sp., it is a cover crop that improves soil fertility, structure, physical, chemical and biological properties and it is a weed control crop.	
Training: visit of the Costa Rican Association for the Study of Weeds (ACEM, by its acronym in Spanish).	The farm is open to students, teachers, and educational institutions, offering field experiences that allow them to directly observe and understand the benefits of agroecological systems, from ecological soil management to biological pest control and the conservation of associated ecosystems.	
Edges with different types of weeds	They increase plant and wildlife diversity, strengthen food webs, and enhance the system's resilience to pests or disturbances.	
Channel edges protected with living covers.	They prevent irrigation canal erosion, improve water infiltration and quality, and act as biological corridors that facilitate the movement of beneficial wildlife.	

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Pesticide Action Network International (PAN) is a network of over 600 participating nongovernmental organizations, institutions and individuals in over 90 countries working to replace the use of hazardous pesticides with ecologically sound and socially just alternatives.
Web: pan-international.org
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IRET (Regional Institute for Studies on Toxic Substances) is an institute concerned about the impact of toxic substances on agricultural systems, the environment, and human health that conducts research and promotes agroecological alternatives for sustainable production.

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