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CIRAD's POSITION

The circular economy, a driver of more sustainable food systems

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Cover photo: 300-kg groundnut roaster, powered by burning groundnut shells. Kadior Céréales SME, Senegal © BioStar

The circular economy, a driver of more sustainable food systems

One of the paradoxes of food systems lies in the fact that they are both victims of and contributors to natural resource depletion, biodiversity loss and climate change, as well as potential political conflicts arising from these pressures. The functioning of food systems is under threat in many regions, which must constantly adapt as their populations continue to grow. At the same time, these systems are often criticised for their lack of efficiency and sustainability, in particular due to their high consumption of natural and energy resources, the significant losses along food supply chains (estimated at around 30%), and their contribution to anthropogenic greenhouse gas emissions (also approximately 30%)[1]. The development of the circular economy is increasingly seen as one of the key ways to significantly improve the efficiency and sustainability of food systems.

"A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" (HLPE, 2014). This corresponds to the concept of an agri-food system, more commonly used by certain organisations, such as FAO.

CIRAD's research on the circular economy focuses on food systems in tropical and Mediterranean countries, which are under significant pressure due to inefficiencies, low productivity, or a combination of these problems.

CIRAD's approach and beliefs

- The circular economy is not an end in itself, but a means, primarily used to address materially unsustainable situations and pathways. To do so, it is essential to go beyond the focus on private initiatives by fostering cross-sectoral actions;
- The food system is by definition the target system for restoring or introducing circularity to help make agriculture and food more sustainable. This implies examining and clearly defining the boundaries of this target system;
- CIRAD is conducting context-specific research on the circular economy within food systems in order to identify and implement the right innovation, creating the right impact, in the right place;
- This is being done with and for the right people: to ensure these changes are lasting, CIRAD places great importance on identifying, involving and fairly representing all stakeholders, including less organised groups such as small producers;
- CIRAD's research demonstrates the impact of the circular economy on food system sustainability and calls for the creation of enabling conditions to support it;
- The scale of this impact then provides a basis for CIRAD and the stakeholders concerned to jointly assess whether a deeper, more structural transformation of the food system is required;
- CIRAD advocates for this approach and implements it with its partners in various geographical contexts, to help to meet the challenges of sustainable development, to reduce environmental and climate footprints, and to achieve global food and nutrition security.

Why combine the circular economy and food systems?

The circular economy can be defined as *"an economic system that replaces the concept of 'end of life' with the reduction, alternative reuse, recycling and recovery of materials* [editor's note: in this case, products, co-products and by-products of the food system] *in production/distribution and consumption processes"*[2]. Its goal is to contribute to sustainable development in an environmentally sound manner, while creating economic prosperity and social equity for future generations[3]. The concept of the circular economy remains controversial, not only because of its unclear theoretical grounds and the structural obstacles to its implementation, but also due to its agenda, which is dominated by technical and economic considerations[4]. It is nevertheless seen as essential in light of the fact that natural, mineral and fossil resources are finite.

The circular economy is increasingly prominent in public policy[5]. Its potential to reduce environmental impacts and contribute to economic development is attracting the interest of local actors[6]. Initiatives in agriculture and food are typically grassroots, sectoral (individual or private) and driven by opportunities for profit or beneficial local relations, rather than aiming to address structural and systemic challenges.

CIRAD views the circular economy as a means to steer the evolution of a situation facing such challenges onto a more sustainable path. This approach leads it to design initiatives within the food system framework, as (1) this framework encompasses all activities that could potentially play a role in this "circular" shift and requires their consideration[7], and (2) the food system is just a concept, but using this concept means defining it in relation to the specific challenge at hand. Where these challenges are concerned, a certain increase in circularity – which is always linked to logistical constraints – is seen as at least a first step toward finding a solution. As such, the geographical location, spatial extent and scope of activity of the food system can be defined and adjusted according to the potential and needs of circularity. The circular economy and the food system are therefore two complementary concepts that must work in tandem.

1. FAO, 2023. ***SOFA***
2. Veyssière-Matino, S., 2023.
3. Kircherr *et al.*, 2017.
4. Corvellec *et al.*, 2021.
5. E.g. Garot law, 2016.
6. Ghisellini *et al.*, 2016.
7. United Nations Food Systems Summit 2021.

This approach sets CIRAD apart from other actors advocating for greater circularity within food systems[8]. Circularity is not a silver bullet that can solve multiple problems and challenges at once: while every sustainable food system includes circularity, not every food system that incorporates circularity is necessarily sustainable. Above all, circularity must be implemented where it is most urgent and most relevant. This perspective leads to context-specific research aimed at identifying and implementing what WWF has recently referred to as the "right innovation" (i.e. systemic changes that are co-designed and cross-sectoral), delivering the "right impact" (in relation to the challenge at hand, taking account of externalities), in the "right place" (in terms of the location, scale and scope of the system)[9], and for the "right people" (in line with CIRAD's strong commitment to ensuring sustainable change through the identification, participation and fair representation of all stakeholders, including groups that are often less structured, such as small producers).

This synthesis highlights the research approach that CIRAD is already applying – and is committed to continuing – as part of its efforts to explore and activate the different drivers of circularity to address the specific sustainability challenges facing food systems.

Improving the efficiency of food systems

There is now a scientific consensus on the need for an in-depth transformation of our food systems to guarantee their long-term viability, particularly to end our reliance on fossil fuels and synthetic chemicals, to improve global health (human, plant and animal), and to ensure a fairer distribution of added value[10]. Food systems are reliant on other systems that are beyond their control and increasingly unstable, such as the climate, energy markets, finance, transport and mineral resources.

In the 2023 edition of *The State of Food and Agriculture*, FAO examines the true cost of food, with a focus on the establishment of sustainable agrifood systems. The report estimates the real costs of agrifood systems, including environmental, social and health-related costs. These are often referred to as "hidden costs", and amount to nearly 10 trillion dollars[11]. While calling for research and innovations that contribute to making agrifood systems more sustainable, FAO is currently conducting targeted, in-depth assessments to prioritise solutions and to guide transformative action.

Optimising the efficiency of the existing food system is an area that needs to be explored before any deeper transformation of this system, by activating the drivers that can have an impact on its sustainability in the relatively short term. Based on these gains, research can then identify whether stakeholders consider a deeper transformation of the system to be necessary.

Rather than setting out the broad principles that should govern a truly circular food system[12] and remaining disconnected from reality, CIRAD is working to identify the most realistic and urgent first steps towards greater circularity.

Circularity, but of what exactly?

It is well-known that a large portion of primary agricultural production never makes it to consumers' plates. Being of organic origin and composition and exposed to the atmosphere and microbial life, the post-harvest (and post-consumption) losses are far from inert, thus gradually losing residual value. Recycling does not therefore mean *reusing*, as is the case with materials like glass, plastic and paper. Any material or part of a material intended for human consumption, once lost for this purpose or consumed, cannot simply be requalified as human food by repackaging it. Requalification can only be achieved through advanced processing techniques; this is generally referred to as waste-to-nutrition, and is the subject of ongoing technological research[13]. These techniques involve biorefinery-type processes, which are difficult to implement in tropical and Mediterranean countries and have uncertain environmental impacts[14].

To achieve circularity, CIRAD focuses on harnessing other values – such as the nutritional value of the residue itself (e.g. in animal feed) –, sometimes referred to as upcycling. Other values lie in various components of these residues (fibres, molecules or elements) and may be of interest to sectors such as energy, packaging, cosmetics or soil fertiliser products.

Circularity... for what purpose?

Circular food systems apply practices and technologies that minimise the use of non-renewable resources, encourage the use of regenerative resources, prevent the leakage of natural resources from the food system, and stimulate the recycling of inevitable resource losses[16].

The development of circular activities is driven by local needs and should be considered at the appropriate level within the definition of the food system. By reducing or avoiding value losses, the requalification of residues can lead to the emergence of new economic activities. However, these are not a fixed set of practices, but rather distinct pathways that should be prioritised according to the relative importance of local challenges. CIRAD identifies three possible goals for improving the efficiency of a given food system, each reflecting a different set of challenges: reducing system inputs; limiting system losses; and increasing system productivity (See table next page).

These goals are not mutually exclusive and are often closely interconnected. However, in each intervention context, one goal typically emerges – at least initially – as the main concern shared by the beneficiaries of a circular solution or by those involved in its design. More than the others, the chosen goal thus shapes the solution itself, as well as the way the food system is defined to achieve the desired circularity. CIRAD develops circular economy initiatives in a wide variety of contexts across tropical and Mediterranean countries, where each of these three core goals may take precedence depending on the situation.

The Scientific Group of the 2020 United Nations Summit recognises that any definition of a food system should meet two essential criteria: it should be suitable for the purpose at hand and it should be sufficiently precise to define policy and programmatic priorities and to guide data collection, modelling and analysis to ensure effective action.

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8. KPMG, 2020
9. WWF, 2023
10. CIRAD, 2022
11. FAO, 2023. https://openknowledge.fao.org/items/d8b6b6d9-4fe3-4589-8b88-cac3f9ccdf0f
12. De Boer et van Ittersum, 2018.
13. Javourez *et al.*, 2021.
14. Javourez *et al.*, 2022. Javourez *et al.*, 2024
15. Van Hal *et al.*, 2019
16. De Boer and van Ittersum, 2018; Van Zanten *et al.*, 2019

This is exactly what drives CIRAD's work on the circular economy. All of our initiatives in this area are aimed at introducing technical changes within the food system. One set of initiatives targets specific interventions within a food system, before considering the broader systemic impact of the change beyond the targeted links. A second set of initiatives addresses the entire food system value chain from the outset, with every link being a potential target for action. Below are detailed examples of such initiatives for each of these two sets.

Fostering different forms of circularity within the food system

CIRAD has been exploring certain forms of circularity for many years. With the aim of improving food security (see below table), it continues to support crop-livestock integration in rural Sahelian areas – which are heavily constrained by low soil fertility and limited resources available to producers – in order to increase the productivity of agricultural systems by making use of manure and crop residues. Research is expanding to include the evaluation of trade-offs in the reuse of this organic matter, depending on the territorial context, between soil amendments, livestock farming and other uses, especially energy. Although studies at the plot, farm and territorial levels have established that rangelands play a key role in the resilience of agropastoral production systems[17], the optimal articulation of these levels of management is still being explored.


Participatory workshop with local equipment manufacturers: designing a boiler fuelled by burning cashew nut shells in Senegal.
© BioStar - T. Ferré

17. Berre *et al.*, 2021; Assogba *et al.*, 2022.

Challenges	Goal	Situations and system
The resilience of the food system, identified as being partly shaped by its dependence on external resources, which are by definition beyond control, is seen as under threat. This threat may stem from the depletion of these external resources, their rising costs, or their excessively high carbon footprint.	**Reducing system inputs**	This concerns situations where the food system in question is "local" or "territorial" in nature, in the sense that the value chains studied share the same space as the population they help to feed. In situations where this concern takes precedence, CIRAD's work focuses on food systems of varying sizes, for which the boundaries, defined from the outset, are the key characteristic. The aim of this work is to make greater use of the system's "internal" resources to replace those coming from "outside." This approach thus primarily explores the use of all locally available resources and the capacity to mobilise them while remaining competitive with other systems or territories.
Losses in the form of residues or waste from one or more parts of the value chain are seen as a problem, because they either hinder economic development or have negative environmental and health impacts; they therefore need to be reduced or eliminated.	**Reducing system losses**	CIRAD is working in situations where specific places and actors are identified as experiencing problems caused by losses, including: • negative externalities, for example the degradation of resources such as water or soil quality, • value losses (or costs) that the activities in question aim to reduce, such as waste with high calorific potential, • barriers to development, for those generating the losses or a third party, as in the case of effluent management, which is subject to strict regulations. Based on these situations, CIRAD studies systems that often go beyond these specific links, for which the definition of boundaries evolves to encompass a range of activities sufficient to ensure systemic and sustainable solutions can be identified.
Improving food and nutrition security is considered a top priority.	**Increasing system productivity**	A traditional, yet still relevant approach to achieving food and nutrition security through strengthening local food production is to boost the productivity of certain links in the value chain. This approach is seen in contexts where rural populations are forced to seek food self-sufficiency as they have limited access to distant markets and external inputs. Alongside this traditional approach, a more recent one has emerged: that of urban areas that attract large amounts of food from afar, while also accumulating significant quantities of nutrients through their waste, by-products and residues, which can potentially increase local supplies to cities. Here, CIRAD studies systems that are defined by the specific relationships to be established between activities and "resources", whose repercussions then help to map out the food system.

In the following sections, CIRAD highlights research focusing on forms of circularity other than crop-livestock integration, in contexts addressing different challenges, in order to illustrate the diversity of its circular initiatives.

Turning food processing waste into bioenergy for local energy security

Most West African countries have only one true rainy season per year, resulting in a single harvest. Crops must therefore be processed and packaged quickly to prevent spoilage, so that they can be preserved and stored to ensure food availability until the next harvest. FAO estimates that 30 to 40% of food products in North Africa and the Middle East are lost or wasted every year due to problems along the food value chain, particularly inadequate storage, transportation and processing facilities. Processing food close to its production areas can significantly reduce these post-harvest losses. However, these food processing operations (drying, smoking, pressing, roasting, hulling, pasteurisation, etc.) require energy. But in rural areas, access to energy is expensive and unreliable, as it is primarily based on the use of imported fossil fuels, with recurrent supply issues and power outages. This lack of access to energy particularly limits the development of agri-food SMEs, forcing them to set up in peri-urban areas. This situation contributes to urbanisation and the decline of rural areas, which become more reliant on agriculture.

At the same time, many food processing SMEs generate organic waste or by-products (cashew shells, shea butter processing waste, mango kernels, rice husks, liquid effluents, etc.). In West Africa, teams from CIRAD are working with national technical and scientific partners to co-develop innovative bioenergy processes that enable the local valorisation of agri-food waste to supply energy for agri-food processing equipment. These SMEs thus use their own processing residues or those from other units in their territory to generate the energy they need. Research is underway on the rice, shea, mango, peanut and cashew sectors in Burkina Faso and Senegal[18]. The goal is to develop small-scale bioenergy processes tailored to the characteristics of the types of agri-food waste from these sectors, which are difficult to valorise and produce large amounts of smoke that can be harmful to the health of operators. Locally manufactured bioenergy equipment (e.g. peanut dryers heated by burning peanut shells, shea roasters heated by burning shea butter waste) is being designed and developed in collaboration with users (agri-food SMEs), local equipment manufacturers and industry organisations.

Training staff from the UTAS SME - Prototype steamer powered by burning cashew nut shells, for shelling nuts © BioStar - T. Ferré

Although improving food security is the main objective here, this research also contributes to strengthening resilience and reducing environmental and health impacts (see box), particularly in peri-urban areas. For food processing SMEs, disposing of these residues also represents a significant cost, as they must be removed from the production site. For example, transforming shea nuts into butter produces sludge that emits gas and foul odours when stored, incurs spreading costs, and harms soil microflora and plant growth. Yet, once decanted and dried using methods developed by CIRAD and its partners, this sludge becomes an excellent fuel, with an energy potential (calorific value) higher than that of wood.

CIRAD has shown that in some sectors (such as cashew and rice), SMEs generate enough residues to produce significantly more energy than they actually need. The next step for CIRAD is to explore and define how this surplus could be used to supply energy to other local SMEs. This means developing scenarios for selling, transporting and storing the biomass, as well as defining the roles and responsibilities of the different stakeholders involved.

Finally, CIRAD is working to ensure that these innovations are shared across the sub-region by the interprofessional organisations. Recognising the relevance of these solutions in meeting the real energy needs of agri-food SMEs, these organisations promote them among their members and networks. This entails capacity-building efforts carried out in collaboration with local institutions, decision makers and donors to create an enabling environment for the development of bioenergy.

Food waste from cities as a resource for nearby livestock farming

Some agri-food waste, which is unfit for human consumption, can be used as animal feed. Feeding livestock with food waste is nothing new, but this urban waste management solution takes on a particular significance in large cities, where ongoing urbanisation puts it at risk, as the practice depends heavily on the close proximity between livestock farming and the production of food waste.

CIRAD has, for example, studied the political, social and economic measures that enable pig farming to continue in the city of

18. BioStar project: https://www.biostar-afrique.org/en
19. Robineau and Soulard, 2017
20. Cesaro *et al.*, 2019

Bobo-Dioulasso in Burkina Faso[19]. These farms rely heavily on the reuse of dolo draff (a brewery by-product) as well as on co-products from urban mills and food waste given freely by local residents. This research shows that the sustainability of this activity depends on agreements between people operating within the same vicinity.

Beyond the fragility of these agreements, these situations are threatened by urban sprawl, as CIRAD and its partners observed in Hanoi, Vietnam[20]. First, Hanoi is seeing an increase in the amount of food waste sent to landfill. Second, farmer-recyclers are no longer able to maintain the same level of recycling activity due to growing urban pressure and structural changes in food production. As invisible actors in the urban metabolism, these farmers work closely with mass catering services to sustain their activities, but their ability to expand is limited by insufficient financial resources and a lack of available land in nearby rural areas. The development of waste collection activities by these farmers is restricted by numerous physical factors, including the volume of waste to be transported, the distance and time between farms and waste suppliers, and their own ability to process the waste on farms. Findings show that the larger their herds, the more waste farmers collect, the higher the price they pay, and the further they must travel. This highlights the main challenge for farmers: the space-time relationship in a changing urban context. Most farmer-collectors say that they are mainly driven by the savings made by using food waste. The energy cost of collection and the time needed are the main physical and economic factors that limit their range. They spend between one and six hours a day on the road collecting this waste. As the demands of this work grow, some farmers are considering professionalising their livestock systems by switching to commercial feed. For the circular economy to continue to benefit the city, it seems that some form of regulation or support for shared labour and private investment is needed.

In a context marked by political ambitions in terms of recycling and the circular economy, as in Vietnam, CIRAD aims to use local assessments to encourage the relevant authorities to: (1) explore the development of policy tools to prevent the loss of these circular practices; (2) take a more systemic approach to tackling the challenge of growth in a city like Hanoi, with its resulting issues, including the management of vast amounts of waste in connection with the nearby agricultural area.

Fostering the circularity of the food system as a whole

Towards island food systems with more autonomous local agricultural production

Island territories, with high population density and growth, are real nutrient sinks (in agronomic terms) because they import a large portion of their food needs, while their exports are minimal. They also import most of the inputs used in local agricultural sectors, such as fertilisers and animal feed. In Réunion, for example, improving circularity within the food system would reduce this reliance on imported inputs, thereby increasing the island's resilience and reducing its carbon footprint. At the same time, it would help to address the development barriers caused by waste accumulation.

In Réunion, only a few sectors – mangos and suckler cows – are not dependent on imports. After extensive research aimed at providing fertilisers made from local waste sources[21], CIRAD has recently taken a more holistic, island-wide approach to exploring the potential for reducing all forms of agricultural dependence on external sources (inputs, animal feed)[22].

Bagasse, sugarcane straw, green waste, livestock effluents, food waste from restaurants and households, and more: all types of "biomass" either already used or with potential for use in agriculture – whether produced on the island or imported – have been identified and characterised, along with the practices of the people who manage them. The flows of these materials, both between sectors and between actors within each sector, have been quantified and partially mapped.

This analysis showed that valorisation does exist but is sometimes suboptimal, and helped to mobilise stakeholders to co-develop forward-looking scenarios at the island level, including: the creation of a "fodder bank" for ruminant farming; the co-composting of green waste and pig slurry on pig farms; the provision of shredded green waste for livestock bedding; and the valorisation of biowaste by installing anaerobic digesters to produce local organic fertiliser. These initiatives are functionally interconnected. By dynamically simulating them using digital tools, it was possible to assess the nature, intensity and spatial variability of their interactions and, most importantly, to evaluate the overall benefit in terms of reduced reliance on imports. The results indicate that, depending on how the initiatives are implemented, their simultaneous emergence can either create competition for certain resources or foster synergies in terms of environmental benefits and greater self-sufficiency.

Despite being publicly supported to accompany population growth, the development of monogastric livestock farming sectors in Réunion is threatened by the sectoral, fragmented management of final waste, with the regulatory spreading of their effluents now in competition with sewage sludge. In fact, because so little land is eligible or accessible for the practical spreading of these effluents, only a small portion of this waste can be disposed of in this way. Faced with the dual challenge of resilience and economic development in these sectors, and at the request of local stakeholders, CIRAD implemented a territorial approach[23] 10 years ago to identify integrated and circular solutions for organic waste management. Due to logistical constraints (high transport costs for the waste to be processed, rugged terrain), this research was not conducted across the whole island, but within a more limited area.

This consultation process identified several valorisation pathways – removing certain residue sources due to their regulatory status as "waste"– that could be implemented in the short term and would partially unlock the development of the pig farming sector. A co-compost made from green waste, slurry and distillery vinasse would be of great interest to the vegetable farming sector, which supplies fresh, nutrient-rich food. However, it also became clear that to expand circularity beyond this outlet, it will be necessary to ensure on-site production of fertilisers, in other words nutrient-rich materials suitable for agriculture. This would require more advanced technical facilities, significant investments, a

21. https://impress-impact-recherche.cirad.fr/activites/impress-ex-post/etudes-de-cas/recyclage-dechets-organiques
22. https://www.cirad.fr/en/press-area/press-releases/2020/circular-bioeconomy-reunion-gabir-project
23. https://www.cirad.fr/en/our-activities-our-impact/priority-research-topics/territory-based-approaches/the-issues

broader collecting area across the whole island, and inter-sectoral organisational support. These conditions have not yet been met, but they are now a key focus for the local public authorities.

The implementation of technical and organisational measures to foster circularity in island food systems often faces a range of obstacles. Some of these challenges are linked to how accurately the risks and benefits of these measures are assessed. CIRAD is continuing to explore various avenues: improving its ability to conduct dynamic, spatialised simulations; and enhancing multi-criteria impact assessments, by reducing and clarifying uncertainties about the agronomic and environmental impacts and giving more weight to the socio-economic impacts.

Additional challenges arise from the local-level implementation of co-developed solutions. In such contexts, where local (re)organisation is required, CIRAD emphasises the importance of providing long-term support to foster the emergence of communities of practice that actively involve the local political level. In doing so, CIRAD aims to explore the effects of implementing public policy tools that may be necessary to make the desired solutions viable. These developments would enable stakeholders to identify the most appropriate solutions and to create the necessary conditions for their implementation and uptake.

Towards circular city region food systems

CIRAD and its partners have recently conducted systemic analyses of several large cities in the global South, conceptualised as city region food systems. In response to challenges related to resilience and food security, FAO uses this concept to foster the consolidation – or restoration – of rural-urban links[24]. The problem posed by large cities, as food and nutrient "sinks", can also present an opportunity, particularly in sub-Saharan African regions where agricultural areas near cities have insufficient access to fertilisers. Fostering city region food system approaches would ultimately enable the hinterland to contribute more effectively and sustainably to the city's food security. Such approaches recognise that urban and rural areas are interconnected through many other sectors and fields (such as economic development, water and waste management, energy, transport, health, urbanisation, and spatial planning)[25].

Together with its local partners and IRD, CIRAD has shown that the food system in Maradi – Niger's second-largest city – and its hinterland still operates with a relatively high degree of autonomy[26]. Agricultural recycling of various types of organic waste plays a role in this, though more efficient recycling could further strengthen this autonomy. It remains to be seen whether this will be enough to keep pace with Maradi's population growth, which is on a similar path to that of Ouagadougou, just 20 years behind. In the case of Ouagadougou, findings suggest that current agricultural productivity in the hinterland limits its ability to feed the city: most of the food produced there is still needed for the subsistence of the rural population itself. However, CIRAD's analyses indicate that several recycling options could be well suited to local conditions. Composting the organic fraction of solid waste, for example, could boost production in the many developed lowland areas around the city.

Agricultural valorisation of a portion of urban urine, which is rich in nitrogen and phosphorus and has low levels of contamination, also appears to be another technically viable option, and is no longer a taboo in this part of the world, including in Muslim-majority countries. The food consumed by people in Ouagadougou, sourced from across Burkina Faso, now represents a third of the nitrogen content of the country's total fertiliser imports. Given the absence of a collective sanitation system and the proven negative impact on water quality, CIRAD now systematically includes nutrient pathways in its research, from the fields through to their release into the subsoil.

It is worth noting that in addition to this research, which explicitly ties in with the city region food systems approach, CIRAD is also implementing numerous other projects that support the agroecological transition in farming systems, such as peri-urban vegetable farming, thereby helping to make these food systems more circular. In Côte d'Ivoire, for example, CIRAD is testing innovations aimed at preventing post-harvest losses, either by maintaining the original quality of fresh produce to avoid these losses, or by identifying new ways to reuse raw materials that are no longer suitable for human consumption[27].

By defining city region food systems based on a target population – urban, in this case –, CIRAD studies systems that are explicitly designed to be open and works to influence them. There is an urgent need to move beyond analyses and estimates by conducting in-depth, forward-looking and participatory research on these systems, leading to the adoption of measures to address the growing imbalance.

This implies considering the potential repercussions the systemic changes planned may have beyond these systems. Their geographical extension could also mean that initiatives aimed at city-region integration will intersect with those aimed at crop-livestock integration, in which case any contribution to stabilising rural populations should be prioritised.

24. FAO defines a city region food system as "all the actors, processes and relationships that are involved in food production, processing, distribution and consumption in a given city region". See: https://www.fao.org/in-action/food-for-cities-programme/overview/crfs/en/
25. Blay-Palmer *et al.*, 2018
26. Wassenaar *et al.*, 2023
27. https://www.projet-marigo.org/

Spreading bunch stalks, a co-product of palm oil extraction. Organic fertilization by recycling palm oil mill effluent. A. Rival © CIRAD

Systemic shifts in food systems: a field to be explored

The circular economy aims to achieve efficiency gains within and between existing systems. This makes it possible to then determine whether more structural changes are needed in these systems. In saying this, CIRAD acknowledges a current limitation of the concept of the circular economy, as discussed by the community in this field[28]: the goal is not to alter consumption, but to adopt "smarter economic models", in which recyclable materials and resources are used efficiently. Critics argue that the impact of efforts to achieve a circular economy is undermined by the fact that waste management policies largely ignore consumption. These policies thus overlook the mechanisms that generate waste in the first place.

If we consider making changes to our entire way of life, it is clear that policies could have a significant influence, for example on food choices. Research into the changes that create the conditions for systemic transformation is still in its early stages, but it could be a useful addition to the current focus on identifying the systemic shifts needed to make certain food systems truly circular[29].

CIRAD's experience in the circular economy shows that the distinction between efficiency gains within existing systems and the transformation of those systems is not straightforward. Its research so far has focused on consensual changes that are, in principle, achievable in the short term within the current sociopolitical and economic framework. However, in the case of Réunion as described above, the co-constructed solution was not viable in the given economic context. As a result, various financial support measures were implemented to make the new local fertiliser production sector competitive. The actual implementation of changes, even when considered consensual by the stakeholders involved in their development, often encounters difficulties in achieving broad uptake by the target communities. It is clear that changes aimed solely at improving the material efficiency of a given food system, without actually transforming it, point to the need for further research on the framework that governs how the system operates. Strengthening the interdisciplinary and integrative nature of this research is crucial, combining contributions from the social and human sciences as well as the biotechnical sciences, to ensure the circularity of food systems.

28. Brizga and El Khadraoui, 2022
29. Van Zanten *et. al.*, 2023

Direct sale of cabbages, Burkina Faso. P. Dugué © CIRAD

Conclusion

Improving the material circularity of a food system is not an end in itself, but it can be an important means – among others – of improving the system's efficiency and thereby making it more sustainable and resilient. CIRAD fosters circularity only where it is identified as a means of: (1) increasing the contribution of local production to food self-sufficiency; (2) reducing dependence on external resources that are non-renewable, increasingly expensive, or have a high environmental footprint; and (3) unlocking the development of sectors in territories facing (or expected to face) high economic and demographic pressures.

While some of the research presented here focuses on agricultural or waste recovery sectors (such as energy), most of the work is rooted in territorial approaches, as seen in the studies conducted in island contexts or on city region food systems. More specifically, within these territorial approaches, there is a need for complementary research, whether to ensure the effective implementation and adoption of the proposed changes, or to explore levels of circularity that can only be achieved through systemic shifts, over and above efficiency gains.

The wide range of global challenges today, including climate change, the depletion of natural resources, and global food and nutrition security, leads CIRAD to explore diverse strategies for the effective and sustainable implementation of circularity, in a given context, as a means to address these challenges. At the interface between various biotechnical, social and human disciplines, CIRAD continues to develop methods and tools to design, test and assess solutions that bring real added value, while also helping to determine what can realistically be achieved in terms of circularity.

The research that CIRAD is planning to conduct in the coming years in the field of the circular economy includes two key focal areas: (1) incorporating political economy to explore flexibility within the rules that govern the food system in question; and (2) strengthening participatory methods with the stakeholders involved and creating the right conditions for lasting communities of practice, to ensure that the innovations and changes developed are ultimately adopted. ■

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It works with its partners to build knowledge and solutions for resilient farming systems in a more sustainable, inclusive world. It mobilizes science, innovation and training in order to achieve the Sustainable Development Goals. Its expertise supports the entire range of stakeholders, from producers to public policymakers, to foster biodiversity protection, agroecological transitions, food system sustainability, health (of plants, animals and ecosystems), sustainable development of rural territories, and their resilience to climate change. CIRAD works in some fifty countries on every continent, thanks to the expertise of its 1750 staff members, including 1200 scientists, backed by a global network of some 200 partners. It also supports French scientific diplomacy operations.

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