> CHAPTER 8

Alternative STI pathways

Three case studies of local STI pathways in Argentina, India and Kenya

AUTHORS

Saurabh Arora
Valeria Arza
Agustina Colonna
Paul N Kombo
Nimisha Mittal
John Ouma-Mugabe
Rasheed Sulaiman V

OVERVIEW

This chapter introduces our three case studies, which map alternative STI pathways in three different locations.

The case studies focus on the following challenges, which relate to a range of Sustainable Development Goals (SDGs) as follows:

- Seed development in Odisha, India, to address climate stresses and other problems facing rice cultivation (relevant SDGs 1, 2, 3, 8, 10, 13 and 15)
- Tackling Chagas disease in Argentina (SDGs 1, 3, 4, 5, 9, 11, 15 and 16)
- Addressing conflicts around overfishing in the Lake Victoria region of Kenya (SDGs 1, 2, 3, 5, 14 and 16)

Each case study was selected for its relevance to multiple SDGs.

Footnotes for this chapter are on page 96. A full list of references can be found on page 140.

What are STI pathways?

Science, technology and innovation (STI) activities can develop in multiple directions. To address this multiplicity, we use the concept of STI pathways.[1] In each area of activity, a diverse range of STI pathways is possible.[2] For example, in transport, one STI pathway focuses on developing vehicles, road infrastructure and regulations for speed and pollution control. An alternative pathway might be structured around infrastructure for cycling and walking, planning cities and towns to minimize commuting distances, and policies that prioritize health and ecology over economic growth.

The pathways concept highlights how individual STIs are always developed within wider social, environmental, institutional and political contexts. Each pathway comprises specific STIs, the actors who develop them, and the institutions that promote and regulate this development. Rather than being simply an output, a pathway is a process that can evolve in nonlinear directions and is simultaneously social, political, ecological and techno-scientific.

Generally, just one or two STI pathways dominate in any area of activity.[4] For example, in agriculture, the internationally dominant pathway focuses on modern STIs such as hybrid and genetically modified seeds, precision agriculture based on artificial intelligence and data analytics, and modern pesticides and synthetic fertilizers.[5] More marginalized are the pathways based on diverse agroecological techniques, non-pesticidal management, rainwater harvesting, and farm-saving of seed varieties that are adapted to local conditions.[6] By directing attention to pathways that are marginalized yet equally effective in addressing sustainability goals (see Chapter 9), the pathways approach can open up new directions of sustainable development,[7] thus reducing the dominance of incumbent pathways.[8]

For each case study (India, Argentina, Kenya), we consider how diverse pathways have evolved to tackle sustainability challenges. Any pathway can be understood in plural ways, and it is impossible to produce a singular self-evident mapping of any pathway.[9] We highlight this plurality of perspectives in Chapter 9. Space limitations mean that our descriptions of the pathways below are necessarily incomplete.

How we identified the pathways

We used a variety of methods to map the diverse STI pathways in our three cases.

In India

We started with a detailed review of journal papers and grey literature, including annual reports of relevant organizations and project completion reports. We then conducted semi-structured interviews with key stakeholders.

In Argentina

We reviewed secondary sources on Chagas and conducted interviews with 13 representatives of five research projects and with seven key informants from policy and non-governmental organizations.

In Kenya

Building on an extensive literature review and a scoping workshop to map the issues and actors, we conducted semi-structured telephone interviews, administered an email questionnaire among key stakeholders, and held focus group discussions.

CASE STUDIES

Diverse pathways for rice seeds in India

Farmers have been cultivating rice in India for at least 7,000 years, growing a vast range of varieties to suit the country's diverse climates and ecosystems. However, this biodiversity has declined rapidly in the last six decades since the country's Green Revolution (GR). The GR saw philanthropists, international agricultural research organizations, development aid agencies, Indian state bodies and private corporations start to promote agricultural modernization based on toxic pesticides, synthetic fertilizers, and 'high-yielding' and hybrid varieties of seeds.[10] In the 1950s, before the GR, more than 100,000 varieties of rice were grown in India. This figure is now estimated to be just 7,000. By the 1990s, the bulk of India's rice production was focused on less than 50 modern varieties.

Below, we describe one STI pathway based on breeding hybrid seeds associated with agricultural modernization, and another pathway that focuses on conserving heirloom varieties of seeds.

The seed breeding pathway

In an attempt to tackle the stresses of droughts, floods and cyclones, agricultural scientists are breeding 'improved' rice seeds that are designed to be high-yielding and stress tolerant. In the state of Odisha, the breeders are based largely at the Government's Indian Council of Agricultural Research (ICAR), the National Rice Research Institute (NRRI) and at Odisha University of Agriculture and Technology (OUAT). Together, the NRRI and OUAT have released about 200 varieties of seeds for Odisha's four main rice ecosystems – irrigated, rainfed-low-land, rainfed-upland and flood-prone – which each face several unique stresses. The actors involved in the breeding pathway and their different roles are listed in Table 8.1.

The seed breeding pathway is dominated by government institutions, with private firms playing a crucial role in the sale of seeds. The role of farmers in this pathway is limited. They are primarily buyers of the seeds, although many cultivate their own farm-saved seeds and exchange seeds with other farmers.

The seed conservation pathway

We identified a second pathway, which promotes seeds grown and saved primarily by Odisha's Adivasi communities, largely through in-situ conservation of 'heritage' or 'heirloom' varieties on farms. These seeds are freely shared, often facilitated by individual seed champions, seed conservationist groups, local civil society organizations and community seed banks (see Table 8.2).

Adivasi people often prefer heirloom seeds for their taste and aroma. These varieties are also used in religious rituals and festivals, and the straw from the rice crops may be used as fodder and to thatch roofs. Heirloom varieties are often

Table 8.1 / Main actors and their roles in Odisha's seed breeding pathway

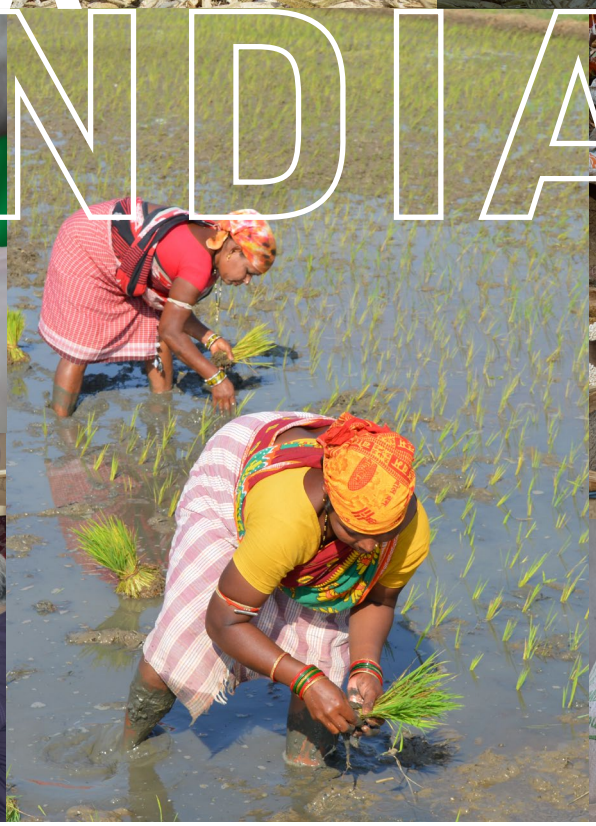
Actors	Roles
Indian Council of Agricultural Research (ICAR)	• Administrative and financial support • Supports the All India Coordinated Rice Improvement Programme (AICRIP) to lead trials
ICAR National Rice Research Institute (NRRI), Odisha	• Researches, develops and releases high-yielding varieties (HYVs) • Collaborates with local Krishi Vigyan Kendras (see below), NGOs and farmer-producer companies to demonstrate the potential of new varieties • Collects rice germplasm
Odisha University of Agriculture and Technology (OUAT)	• Researches, develops and releases HYVs • Coordinates a local AICRIP centre to evaluate new varieties and maintain germplasm • Manages a regional research and technology transfer station
Krishi Vigyan Kendras (district centres set up by ICAR to provide farm support)	• Organizes on-farm testing of new varieties plus demonstrations and training to promote new HYVs
Odisha Department of Agriculture & Farmers' Empowerment	• Promotes HYVs and hybrid varieties recommended by OUAT • Implements government programmes to promote new varieties, such as providing subsidies and organizing demonstrations
Odisha state seed Corporation (OSSC)	• Produces certified seeds through programmes involving growers • Sells certified seeds through government shops and private seed sellers
Odisha State Agro-Industries Corporation	• Public sector marketing channel for seeds
National Seeds Corporation	• Supply of rice seeds beyond Odisha, particularly for programmes such as the National Food Security Mission (NFSM) and Bringing Green Revolution to Eastern India
International Rice Research Institute (IRRI), the Philippines	• Provides access to global elite rice germplasm • Trains scientists in modern rice breeding methods
IRRI Odisha State Office	• Promotes 'climate-resilient' varieties of rice in collaboration with OSSC, Department of Agriculture and NGOs, using field-level evaluation, cluster demonstrations, training and other capacity development
State Seed Testing Laboratory (SSTL), Government of Odisha	• Tests seed samples for quality • Facilitates validation and certification of local rice varieties collected from different parts of Odisha • Trains seed growers and traders in seed testing technology
Seed growers (about 5,000 registered with OSSC) and seed producer groups	• Grow seeds that can be submitted for validation, certification and labelling (facilitated by SSTL)
Private sector seed companies	• Supply roughly 5,000 metric tonnes of rice seeds every year

ODISHA INDIA

CASE STUDY

We studied two contrasting STI pathways relating to the breeding of rice seeds in India. The first involves hybrid seeds, which have been designed by agricultural scientists to be high-yielding and to withstand the stresses of droughts, floods and cyclones. The second pathway focuses on conserving heirloom varieties of seeds. These seeds are freely shared, often facilitated by community groups.

SDGs related to this study:



All photography courtesy of CRISP.

Table 8.2 / Main actors and their roles in Odisha's seed conservation pathway

Actors	Roles
Civil society organizations including Pragati, MS Swaminathan Research Foundation, and Living Farms	• Document hundreds of farmer-led (heritage or heirloom) rice varieties and promote their cultivation as well as the selection of seeds for saving • Organize seed exchanges and community-based seed banks • Provide training to farmers on seed quality and storage
Individual seed champions	• Revive critically endangered varieties, often through organic cultivation on own land • Collect, cultivate, conserve and share hundreds of heirloom varieties, sometimes in collaboration with CSOs
Seed growing farmers (mainly Adivasi) and their groups	• Conserve and grow heritage or heirloom varieties of rice • Share them freely with other farmers
State Seed Testing Laboratory (SSTL), Government of Odisha	• Collects heirloom varieties from farmers and prepares them for validation • Evaluates the quality characteristics of heirloom varieties collected from farmers

claimed to be less vulnerable to pests and diseases. They can withstand drought and water logging, and the Adivasi farmers who grow them generally use very few, if any, synthetic fertilizers and pesticides.

Unlike the breeding pathway, the conservation pathway has received very little support or investment from public institutions or private businesses, although some civil society organizations have carried out seed conservation work as part of larger government programmes such as the Women Farmers Development Programme.

Due to the public support and investment it receives, the breeding pathway dominates rice seed production in Odisha. Seeds developed in this way are often sold by private firms and are widely adopted by large, medium and small farmers. In contrast, as noted above, heritage and heirloom varieties saved on-farm are used largely by smaller Adivasi farmers.

Pathways of research into Chagas in Argentina

Argentina has one of the world's highest rates of Chagas or American trypanosomiasis – a disease associated with a parasite hosted by the triatomine insect, also known as the kissing bug. The spread of Chagas is a complex socio-ecological issue,[13] a function of ecological as well as socioeconomic conditions, including industrial and agricultural production, housing, and unequal access to quality health care and education.

We studied five research projects, spanning the social and natural sciences, that are aiming to tackle Chagas in Argentina. Among these projects, we identified two main pathways: conventional science (CS) and open science (OS). These descriptions are based on the practices within projects, rather than projects as a whole. Social, environmental, institutional and political contexts are often crucial in determining whether a particular research project follows the OS or CS pathway.

Conventional science pathway

CS is driven by competition, not just in corporate science but also across universities and public research institutions.[14] Science and technology ministries and organizations compete for resources with other sectors, and scientists themselves compete in many ways: for example, to attract research funding and advance their careers through patents, publications, consultancies and membership of panels.

In CS, most output is published in academic journals behind paywalls or locked behind intellectual property rights. It promotes a particular model of science's relationship with wider society, in which impact is sought through the 'transfer' of techno-scientific outputs. The outputs are designed to be further developed and used by stakeholders in markets and civil society. This linear approach has been critiqued since the 1980s,[15] and several alternative models of knowledge production have been promoted. Arguably the most prominent non-linear model is 'Mode 2',[16] in which scientific research is observed to be produced 'in the context of application'.[17]

The studied projects include an Argentinian public-private partnership to develop a Chagas diagnostic kit. This project uses CS practices. Access to data about the analytical and clinical evaluations is restricted, and the kit will eventually be sold for profit by the private firm.

In another project that uses CS, Chagas advocacy NGOs worked in collaboration with a data science firm to develop a risk map using mobile phone data to identify the Argentinian regions that are likely to have the highest incidences of Chagas and sanitary vulnerability. In line with CS practices, researchers alone made the methodological decisions about what constitutes 'risk' and 'vulnerability' and how to measure them.

CASE STUDY

Argentina has one of the world's highest rates of the disease Chagas. We identified two main pathways for tackling the disease. The first, conventional science, includes studies that are published in academic journals or locked behind intellectual property rights. The second pathway involves open science projects – such as open research databases and citizen science – which provide open access to research outputs and involve collaboration beyond academia.

ARGENTINA

SDGs related to this study:

Images taken from a video on Chagas Research, produced by CONICET Nordeste, Argentina.
https://www.conicet.gov.ar/con-micro-y-nanotecnologia-desarrollan-nuevas-alternativas-para-tratar-el-chagas/

Open science pathway

We characterize OS as using two sets of practices,[18] as follows:

a) opening up *access* to intermediate and final outputs of research, including data, software codes and research papers
b) *collaboration* with others in intradisciplinary, interdisciplinary or transdisciplinary ways, including citizen science and open-source drug development.

All five of the projects we studied involved some collaboration, often going beyond universities to involve transdisciplinary knowledge production with a business or policymaking organization. However, transdisciplinary research that involved patients with Chagas disease was rare.

In just one of the projects that addressed Chagas disease as a multidimensional socioeconomic and ecological issue, researchers worked closely with affected communities and collaborated with schools and universities to develop educational

Table 8.3 / Open science practices across five projects in Argentina

PROJECTS	DIAGNOSTIC KIT	ONLINE DATABASE for tropical disease pathogens	COMMUNITY-BASED EDUCATION about Chagas	APP to show the geographical distribution of the kissing bug	RISK MAP of the Chagas epidemic
COLLABORATION					
What aspects involved collaboration?	Much of the research process	Defining the research agenda and initial phase of the project	Entire research process, including project development and engagement	Geotagged data on the distribution of the kissing bug	Data analysis: combining mobile phone data with socioeconomic information
How was this achieved?	Team formed through a funding scheme to promote public-private initiatives	Collaboration promoted by funding bodies	Through the multidisciplinary team's commitment to openly welcoming new members	Mobile phone app	Philanthropic funding initiative and networking
Who were the collaborators?	Research centres and a private firm	Academic community and the private sector	Academic and civil society organizations, artists, teachers, students, community members	Research centres, county governments and wider community	Academia, NGOs and the private sector
ACCESS					
What aspects were made accessible?	None	Open-access database	Reports, books and leaflets; community workshops; public engagement activities	Access to databases on the geographical distribution of kissing bugs across Argentina	Final outputs; municipal level data on Chagas prevalence and quality of sanitary services
How was this achieved?	n/a	Online platform	Website; activities in hospitals, libraries, museums and schools	Open-source app and website	Intermediate data accessible online
Who were the collaborators?	n/a	Researchers in public and private sector	Academic and civil society organizations, artists, teachers, students and community members	General community, academia and policy	Policymakers and academic researchers

programmes. The project also involved exchanges with a social movement, a museum and groups of artists. Outputs included audio-visual materials, books and information brochures – all openly accessible and written in non-specialist language. This project included researchers from diverse backgrounds (including molecular biology, entomology and social science).

Open-access practices differed across the projects (see Table 8.3). One project involved an open-access database of genome sequences and protein structures of tropical disease pathogens, along with information on targets for drugs. The intended users are researchers in drug discovery. While the platform is available to all, the technical nature of the information means that only a small group of researchers are able to access it.

In the risk map project discussed above, the two final papers were made openly available, along with indicators developed in the project. However, access to the mobile phone data used to develop the indicators was restricted due to a contractual embargo involving a firm. This is an example of how the wider context can constrain OS and promote conventional (closed) research practices.

STI pathways to address fishing conflicts in Kenya

Lake Victoria (LV) connects Kenya, Uganda and Tanzania, covering an area of 69,000 km². It has historically been home to more than 500 endemic fish species,[19] many of which, including the Victoria tilapia, are now considered endangered.

The LV region accounts for about 75% of Kenya's fish production.[20] Between 1954 and 1963, the British colonial Government introduced the Nile perch to LV, claiming it would reduce fishing pressure on endemic species, including the Victoria tilapia.[21] However, the Nile perch turned out to be a damaging predator. By 1998, about 100 species of fish endemic to LV entered the International Union for Conservation of Nature's Red Book of endangered species.[22] Alongside the introduction of the Nile perch, causes of declining fish populations include changes in catchment processes, and increased fishing intensity, largely due to industrial fishing.[23] The combined effect is conflict around fishing in the LV region.

Conflicts exist between fishing communities in Kenya, between Kenyan counties, and between Kenya and other countries in the LV Basin. They involve disputes over fishing zones and quotas, often leading to violence, theft and loss of human life.[24] The Government of Kenya believes that illegal, unregulated, and unreported fishing (IUUF) and overfishing are among the main causes of conflicts in Kenya's LV Basin, and is attempting to address these issues through three main STI pathways, outlined below.

Monitoring, control and surveillance pathway

The Kenyan Government has worked with the Kenya Coast Guard Service, Kenya Fisheries Service, the Kenya Police Service, and beach management units (BMUs) to intensify monitoring, control and surveillance (MCS) systems.[25]

BMUs in each area include representatives of fishers, the Coast Guard and Fisheries Service. They use a voluntary, community-based, consultative approach to monitor and control IUUF and overfishing. The BMUs share information about changes in fish stocks and help set voluntary fishing restrictions during particular seasons in certain zones of the lake. They use social media to promote awareness among fishers and the local community about the impact of IUUF and overfishing on food security and local economies.

In addition, there is state-led policing of IUUF and overfishing, with judicial institutions settling disputes and issuing penalties. Policed MCS relies heavily on smartphone technologies but, according to our interviewees, this is hampered by a lack of access to smartphones and poor internet connectivity. The use of geographical positioning systems and satellite technologies is similarly limited.

Interviewees told us that MCS tends to be hampered by state agencies' lack of enforcement, particularly among the powerful industrial fishing sector (see Chapter 9).

Cage aquaculture pathway

Local and national governments are also promoting alternative sources of fishery incomes. Cage fishing has become increasingly popular on the Kenyan side of the LV basin since the mid-2000s, and was supported by an economic stimulus programme in 2009. By 2019, there were 3,696 cages across the Kenyan LV region.[26]

In our mapping, we focused on the sub-county of Bunyala, home to around 160 active cage fishers. We conducted site visits and interviews between August 2020 and February 2021 and identified four different groups of cage fishers:

(a) registered **private companies**, often also involved in constructing cages, culturing young fish and producing fish feed
(b) a few powerful **individuals** politically connected to the Busia County government
(c) three **women's cooperative associations** linked to the Catholic church
(d) **small-scale farmers**, transitioning from artisanal fishing in the lake

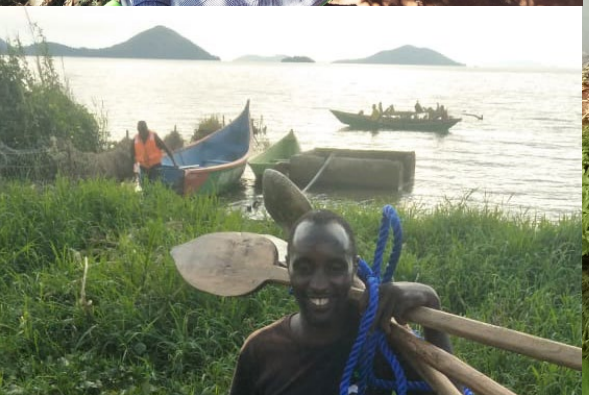
As in the wider LV region, a majority of the cages in Bunyala were owned by groups (a) and (b). The small-scale cage fishers were financially supported by at least three Savings and Credit Cooperative Organizations, and a micro-finance institution – the Kenya Women Finance Trust – supported the women's groups' investments in cage fishing.

LAKE VICTORIA REGION KENYA

CASE STUDY

Conflicts over fishing zones and quotas in the Lake Victoria Basin often lead to violence, theft and loss of human life. The Government of Kenya believes that illegal, unregulated, and unreported fishing and overfishing are among the main causes of conflicts and is attempting to address the problems through three main STI pathways: monitoring, control and surveillance; cage fishing; and pond fish farms.

SDGs related to this study:



Photography: Fred Juma and Paul N Kombo

National government agencies and local government departments also play a part in this pathway – designing regulations, issuing licences and conducting environmental impact assessments (EIAs) for cage fishing. Meanwhile, public universities provide technical support for managing fish diseases, genetics and breeding, and addressing the environmental consequences of cage farming.

Some local and international NGOs also support cage fish production in the area, training fish farmers in sustainable practices and working with policymakers to strengthen EIAs and regulatory governance.

Pond fish farming pathway

Pond fish farms are increasingly being developed and managed by private companies, small-scale farmers, and women's groups. Women are supported by national and local governments through credit and training in pond fishing, and are estimated to own about half the fish ponds in Bunyala. Other actors in this pathway include international donors, funders, university researchers and NGOs.

The NGOs Farm Africa, World Neighbours, Smart Fish, ASRECA, IUCN and ActionAid all work with farmers, government authorities, communities and local researchers to promote sustainable pond fishing. They provide training, share knowledge, offer technical advice and provide access to equipment. Some NGOs also lobby for public policies to ensure that small-scale fishers are not excluded or marginalized.

Many farmers use their own homesteads for pond fishing while some make use of idle land around the lake shores. Ponds constructed on homesteads by small-scale farmers can be as small as 500-600 m², while those used by large-scale farmers can be as large as 80,000 m².

Our respondents reported a lack of policy and legal frameworks to regulate pond fish farming. Another issue relates to land tenure, which one respondent from an international NGO described as "a main policy impediment to advancing sustainable on-land fish farming". Many households of fishers, especially women, do not have the title deeds of the land they are settling on, so cannot invest in improvements. In general, respondents observed a lack of government commitment to supporting fishers (see Chapter 9).

Notes

1. Stirling 2009; Leach et al. 2010.
2. Arora et al. 2019.
3. Bijker et al. 2012; Nelson 1994; Foxon 2011.
4. Arora and Stirling 2021; Arora et al. 2019.
5. Kumbamu 2020.
6. Khadse et al. 2018; Arora 2012.
7. Stirling 2009; Arora et al. 2019.
8. Stirling 2018.
9. Arora and Stirling 2021.
10. Panda and Pathak 2019.
11. Parayil 1992; Sharma 2019.
12. Hardon 1996.
13. Sanmartino et al. 2015.
14. Birch 2020; Slaughter and Rhoades 2005; Slaughter and Leslie 1997.
15. Kline and Rosenberg 2009.
16. Gibbons et al. 1994.
17. Foray and Gibbons 1996.
18. Arza and Fressoli, 2018.
19. UNEP 2006.
20. KNBS 2019.
21. Pringle 2005.
22. Witte et al. 1999.
23. Mbuga et al. 1998; Ntiba et al. 2001; Nyamweya et al. 2020.
24. Mukasa et al. 2019; Smith 2017.
25. Etiegni et al. 2011.
26. KMFRI 2019.