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Rythu Sadhikara Samstha
Farmer Empowerment Corporation

AGRO-INDUSTRY *versus* AGROECOLOGY?

Two macroeconomic scenarios for 2050 in Andhra Pradesh, India

AGRO-INDUSTRY *versus* AGROECOLOGY?

Two macroeconomic scenarios for 2050 in Andhra Pradesh, India

AGROECO
2050

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Executive summary

It is no longer feasible to look at agricultural livelihoods, food, health and the management of natural resources in isolation. The 2030 Agenda for Sustainable Development stresses the urgent need to take concerted action and pursue policies directed at transformational change. It calls for a new agricultural approach to achieving multiple benefits to ensure sufficient, safe and nutritious food through a stable multifunctional landscape, while respecting human rights.

In India, agrifood systems are under increasing pressure to meet nutrition, health and poverty eradication targets while reversing the depletion of water tables, soil degradation, deforestation, land degradation and threats to agrobiodiversity. In addition, climate change impacts related to rising temperatures, increasing frequency of extreme weather events, shifts in precipitation and hydrology, will expose the country to increased vulnerability and threats.

Systemic challenges require systemic solutions. Ending poverty and achieving zero hunger, while ensuring inclusive growth and sustainably managing the planet's ecosystems in the context of climate change and loss of biodiversity, will only be possible through holistic and integrated approaches.

This book summarizes the findings of the foresight study "AgroEco2050" (2019–2022) jointly carried out by Rythu Sadhikara Samstha (RySS), Department of Agriculture of the Government of Andhra Pradesh, the French Agricultural Research Centre for International Development (CIRAD) and the Food and Agriculture Organization of the United Nations (FAO).

The **AgroEco2050 foresight** process was based on the collective expertise and vision of a multistakeholder group that worked together in India from 2020 to 2022, as well as a unique statistical overview of past structural transformations from the 1970s to 2019 in India (in terms of land use, population, employment, sectoral economic growth, productivity). The group quantified dimensions of two rather comprehensive scenarios for Andhra Pradesh (AP), a State of South India with 53 million inhabitants in 2020 and 9.3 million farmers. One scenario focuses on intensification of the Industrial Agriculture model which is currently dominant worldwide, and the other on a full agroecological transition (AE) through natural farming (NF). The model Agribiom-India and its interface, which was developed and customized for this participative foresight exercise (B. Dorin, CIRAD) was used interactively by the group to test the coherence and adjust the assumptions made for both scenarios.

Natural farming is developing in India. In Andhra Pradesh, agroecology-based natural farming is practiced through the Andhra Pradesh Community-managed Natural Farming programme (APCNF), supported since 2016 by the Government of Andhra Pradesh (GoAP) to promote rapid inclusive economic growth, farmer's happiness and healthy food. The programme supports farmers' transition from conventional, chemical-based agriculture to natural farming. The number of farmers practicing NF partially or fully has gone up from around 40 000 in 2016 to 700 000 in 2020–21—an increase of 17 times in 4 years. The intention is to reach all farmers in the state by 2031 (an estimated six million farmer households). If it succeeds, Andhra Pradesh would lead the establishment of a new food systems approach on the subcontinent that would address the ecological, financial, nutritional and social challenges in an integrated manner. At the world level, APCNF could become the first example of a massive scaling-up of agroecology through a single programme. In this regard and to further sustain its vision and work, in 2018 the GoAP requested CIRAD and FAO to partner in conducting a foresight exercise on agriculture by 2050, with a scenario showing the potential impacts of a conversion of its million farmers to Natural Farming.

Foresight is a general term to describe an action-oriented, scientific study of the future. It is a systematic, collective, medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilizing joint actions. It suggests possible, probable and preferred futures; but foresight work never makes specific predictions or forecasts, unlike, say, the weather bureau.

The scenarios built in foresight exercise, and in this particular study, are "ideal types" and are not precise forecasts. They don't pretend to be predictions of the future. The purpose is to present the main storylines or elements of the scenarios. The ideal type is an abstract model which, when used as a standard of comparison, unveils aspects of the real world in a clearer, more systematic way, to help understand the potential implications of a particular pathway that societies may take. It is a "constructed ideal" used to present an approximation of reality by selecting and accentuating certain elements. Each and every element of the ideal types mentioned in this book may not be found in the real world.

This **scenario-building exercise had three main objectives**: to provide an image of what a complete transition of Andhra Pradesh to agroecology could look like, especially to better understand the conditions of such a transformation; to compare this ideal type of transformation with that of Industrial Agriculture (IA) which has guided public policies, industries, agricultural production and food since the 1960s in India; to contribute to national and international debates and research on the future of food and agriculture including Agroecology (AE), with the overall aim of transitioning towards sustainable food systems, leaving no one behind.

Both our **scenarios** foresee an Andhra **population** of almost 60 million inhabitants in 2050 (compared to almost 53 million in 2019, and 33 million in 1980), with more than 35 million adults of working age (the "labour force"), considered here between 20 and 64 years-old (as opposed to 15–64 years found in the literature for decades, without updating the steady and desired increases in education and study levels).

In the **AE scenario**, about 93 percent of the 20 to 64 year-old adults would be employed (against less than 70 percent in 2019), including 10 million in agriculture and allied activities, which would represent 30 percent of the workforce (against 42 percent in 2019 and 60 percent in 1980). This would be a net increase of 700 000 farmers compared to 2019, or as many farmers as in the early 1970s. In the AE scenario, all farmers would practice NF in 2050. In doing so, they would regenerate degraded soils and ecosystems with complex multi-crop-livestock landscapes including rich soil microbiomes and trees. Without touching current forest or shrub areas, they would even cultivate 2 million hectares (ha) more than in 2019, totalling more than 8 million ha in 2050, reversing past trends of desertification and increase in fallow areas as NF would enable the regeneration of dry and degraded lands. This full-employment scenario largely based on agriculture and allied activities, coupled with larger cultivated lands and the low-input but high-output practices of NF throughout the year, would lead to a high growth of the gross value added (GVA) in agriculture (6 percent per annum over 2019–2050, against 4 percent over 1980–2019), as well an all-sectors economic growth of 6.5 percent per annum (against 5.8 percent over 1980–2019). With this AE scenario, AP would then be embarked on in what we call a "Farmer-Developing" path (FD), where farmers are more numerous but where their income gap with non-farmers is narrowing, unlike in the past decades (1980–2019), which were deeply marked by "jobless growth" and a growing agrarian crisis.

By contrast, in the **IA scenario**, unemployment among the 20 to 64 year-olds would remain at the disturbing level of 30 percent in 2019. Indeed, in this scenario, the automation of human activities and energy consumption would accelerate, in particular in agriculture where the number of farmers would be almost halved, from 9.3 million adults in 2019 to 5 million in 2050, or from 42 percent of the workforce to 20 percent. These remaining farmers would all practice industrial farming. They would specialize in few products (paddy, palm oil, cotton, silk, cows' milk, chicken, aquaculture, fruits and vegetables) which they would produce with capital- and input-intensive techniques (genetically modified organisms, synthetic fertilizers, pesticides or antibiotics, hydroponic greenhouses, robots, precision agriculture, artificial intelligence, etc.) largely through export-oriented contract farming with large Indian or foreign agribusiness multinationals. For this form of agriculture to be competitive, only best and city-centric land would be exploited. Fallow areas would then continue to increase, as in the past, from 2.4 million ha in 2019 to nearly 3 million in 2050, which, combined with increasing urbanization, would reduce the cultivated area to 5.5 million ha in 2050 (6.2 million in 2019).

All in all, with less land and farmers, but also higher costs of production, the agricultural GVA would increase only by 3.5 percent per annum on average over 2019–2050 (4 percent over 1980–2019), which, coupled with a rather high unemployment rate (hence less demand), would lead to an overall GVA growth of 6 percent per annum over 2019–2050. This last assumption is lower than in the AE scenario (6.5 percent) but remains optimistic compared to past trends (5.8 percent over 1980–2019), with the strong assumption that the factors of production (soil, water, air, biodiversity, human health, etc.) would not deteriorate further in this scenario, although many believe otherwise. With all these assumptions about the future in 2050 in an Industrial Agriculture scenario, AP would then be embarked on a "Farmer-Excluding" path (FE), where farmers are fewer in number but with an ever-growing income gap with non-farmers, as in the past decades (1980–2019) marked by a deep agrarian crisis and farmer protests, but also ever-increasing agricultural and food subsidies to mitigate negative impacts as much as possible.

In both scenarios, the average **income of farmers** would be multiplied by about 5.5 compared to 2019 (all in constant 2011–12 rupees), to reach about INR 3 000 per day and per farmer (or nearly INR 1.1 million/year). Farmers would then earn almost the same, but for different reasons: in the IA scenario, farmers would produce more calories per hectare (almost 44 000 kcal/day against 36 000 in the AE scenario) and each on a larger area (1.11 ha/farmer on average against 0.83 ha in the AE scenario, and 0.67 ha in 2019), but at higher costs and lower nutritive quality: in the AE scenario, each farmer would earn 10.3 paise (a paisa is 1⁄100 of a rupee) per kilocalorie produced, while it would be 6.1 paise in the IA scenario (moreover without deducting capital costs for machinery and others, which are much higher in the IA scenario).

However, a **farmer–non-farmer income gap** (i.e. difference in average incomes between farmers and non-farmers) would remain in both scenarios. It would be less than in 2019, but would still represent 47 percent of the average income of IA farmers in 2050, and 22 percent of the average income of AE farmers (against 62 percent in 2019). In countries of the Organization for Economic Co-operation and Development (OECD), this average income inequality between farmers and non-farmers was narrowed by a drastic reduction in the number of farmers, allowing those remaining to run increasingly large and robotic industrial farms with various direct and indirect public support. In our Indian AE scenario, there is no dream of such capital, energy and land-intensive agriculture for very few farmers; the vision (also evidenced in the past through abundant scientific literature) is that production of food and environmental services is more efficient when farmers operate at a small scale. But while small farm size can cause agriculture to become more efficient and productive per hectare, it also prevents individual farmers from increasing their income through farm consolidation and robotization, as has happened in OECD countries.

To make up for this, farmers could then be remunerated for their **environmental services** (currently unpaid), which they provide when following agroecological approaches. This could help close the remaining income gap between farmers and non-farmers in 2050. With AE, these environmental services to local and global societies would be numerous, such as water saving and filtering, storage of soil organic carbon and mitigation of climate change, protection of pollinators and biological control agents, resilience to biotic and abiotic shocks thanks to highly biodiverse agroecosystems. payments for ecosystem services (PES) could be granted to each farmer (whether cultivator or labourer) after evaluating and monitoring the extent to which their village or region practices agroecology providing multiple ecosystem and health services.

In our AE scenario, these PES would then amount to about 5.7 percent of Andhra's gross domestic product (GDP) in 2050, which would completely close the average income gap between farmers and non-farmers. By contrast, the **cost of policies to reduce income inequalities** would be much higher in the IA scenario than in the AE scenario (and they would not boost environmental services, as they do in the AE scenario). In the IA scenario, policies to reduce income inequalities could deploy instruments adapted to its logic: price support and input subsidies (to credit, insurance, power, irrigation, chemicals, genetics, robotization, etc.) as today but on a higher level (6.8 percent of the total GVA in Andhra Pradesh in 2050, against close to 2.5 percent in the late 2010s in India) to really close the farm–non-farm labour productivity gap, and universal basic income (UBI) for the unemployed, which, if it amounted to only 25 percent of the average income of non-farmers, would then represent 11.4 percent of the Andhra GDP in 2050. In the quasi-full employment AE scenario, this percentage would be reduced to 1.9 percent. Overall, such policies to reduce inequality would cost more than 18 percent of GDP in the IA scenario, while it would cost less than 8 percent in the AE scenario, with in addition a much higher efficiency on various fronts, for example inequality, environment and health.

Last, but not least, we show that after combining the anticipated cultivated areas and annual yields of each scenario, the total **food production** for 2050 expressed in kilocalories (kcal) per inhabitant would be significantly **higher in the AE scenario** than in the IA scenario (5 000 kcal/capita/day against 4 050, and 3 660 kcal in 2019). As previously mentioned, this AE food production would also be much more balanced and healthier than today and in the IA scenario.

Overall, our two scenarios illustrate two possible but radically different visions of agricultural science and productivity, of societal goals and choices, with their own trade-offs and necessary transformations in both. Compared to the current techno-centric and capital-intensive industrial agriculture and food that the IA scenario would amplify, our expert group was predominantly in favour of the **AE scenario**, because this AE scenario would be:

- **more productive** in terms of useful biomass per inhabitant;
- **more resilient** to economic, climate and biotic shocks;
- **more labour intensive** than capital intensive;
- **more profitable** for farmer households since their input costs would be cut, their diverse, tasty, nutritious and healthy foods could be better priced on local and international markets, and their coproduction of environmental goods or services would be paid for their local or global values, such as safe water, biodiversity reservoirs, soil fertility, nutrient recycling, pollination, combat diseases or floods, mitigation of, and adaptation to climate change.

These multiple benefits (or positive impacts) of the AE scenario would also enable India to achieve multiple Sustainable Development Goals (SDGs) of the 2030 Agenda to respond to pressing economic, social and ecological challenges and global commitments.

	2019	2050 Scenario 100% Industrial Agriculture	2050 Scenario 100% Natural Farming
Population (million capita)	**52.6** (+1.2%)*	**59.5** (+0.4%)∞	**59.5** (+0.4%)∞
Labour force (20-64 years)	32.5	35.4 (+0.3%)∞	35.4 (+0.3%)∞
Unemployment (of the 20-64 years)	10.1 (31%)^	10.6 (30%)^	2.4 (7%)^
Employment	22.4 (69%)^	24.8 (70%)^	33.0 (93%)^
- Farmers	9.3 (42%)^	5.0 (20%)^	10.0 (30%)^
- Non-farmers	13.1 (58%)^	19.8 (80%)^	23.0 (70%)^
Cropland area (million ha)	**6.2** (–0.0%)*	**5.5** (–0.4%)∞	**8.3** (+0.9%)∞
Hectare per farmer	0.67 (+0.9%)*	1.11 (+1.7%)∞	0.83 (+0.7% p.a.)∞
Gross Value Added (10^{12} INR)□	6.1 (+5.8%)*	**36.9** (+6.0%)∞	**42.7** (+6.5%)∞
- Farm sector	1.9 (+4%)*	5.4 (+3.5%)∞	11.2 (+6%)∞
- Non-farm sector	4.2 (+7.3%)*	31.5 (+6.7%)∞	31.4 (+6.7%)∞
Productivity (INR/day)□	**741** (+5.3%)*	**4 080** (+5.7%)∞	**3 545** (+5.2%)∞
- Cropland (per ha)	815 (+4.0%)*	2 670 (+3.9%)∞	3 719 (+5.0%)∞
- Farmer (per worker)	544 (+5.0%)*	2 967 (+5.6%)∞	3 080 (+5.8%)∞
- Non-farmer (per worker)	880 (+4.8%)*	4 359 (+5.3%)∞	3 748 (+4.8%)∞
Plant food production (Gkcal/day)	**193** (+2.4%)*	**241** (+0.7%)∞	**298** (+1.4%)∞
- Per hectare (kcal/day)	31 095 (+2.4%)*	43 854 (+1.1%)∞	36 000 (+0.5%)∞
- Per farmer (kcal/day)	20 740 (+3.3%)*	48 729 (+2.8%)∞	29 808 (+1.2%)∞
- Per capita (kcal/day)	3 669 (+1.1%)*	4 054 (+0.3%)∞	5 008 (+1.0%)∞
Structural Path	Farmer Excluding	Farmer Excluding	Farmer Developing
Income gap between farmers and non-farmers (INR/day)□	336 (62%)μ	1 392 (47%)μ	668 (22%)μ

Structural path: as defined by Dorin *et al.* (2013)
Ha: hectare; INR: Indian Rupee; Gkcal: giga kilocalories
* Growth rate per annum 1980-2019 (39 years)
∞ Growth rate per annum 2019-2050 (31 years)
□ Constant/Real Indian rupees of 2011-12
^ Category share for the concerned year
μ Share in average farmer income of the gap non-farmer income less farmer income

Source: B. Dorin for this publication

Abbreviations

AE	Agroecology, agroecological
ALM	Agribiom Lewisian sub-Module
AP	Andhra Pradesh
APCNF	Andhra Pradesh Community-managed Natural Farming
CGIAR	Consultative Group on International Agricultural Research
CIRAD	French Agricultural Research Centre for International Development
CIRED	International Research Centre on Environment and Development
crore	indicates 10 million
CSH	Centre de Sciences Humaines, Delhi
EG	Expert Group
EPW	Economic and Political Weekly
FAO	Food and Agriculture Organization of the United Nations
FD	Farmer Developing
FE	Farmer Excluding
GAEZ	Global Agro-Ecological Zones
GDP	gross domestic product
GIZ	German Corporation for International Cooperation
Gkcal	Gigakilocalories
GMOs	genetically modified organisms
GoAP	Government of Andhra Pradesh
GOI	Government of India
GVA	growth value added
IA	Industrial Agriculture
ICAR	Indian Council for Agricultural Research
ICRAF	Center for International Forestry Research – World Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
INR	Indian National Rupees
INRA, INRAE	National Research Institute for Agriculture, Food and Environment
IPES	International Panel of Experts on Sustainable Food System
kcal	Kilocalories
MEA	Millennium Ecosystem Assessment
NCOF	National Centre for Organic Farming
NF	Natural Farming
NGO	non-governmental organization
NITI	National Institution for Transforming India
NSO	National Statistical Office
OECD	Organization for Economic Co-operation and Development
Paisa	1/100 of a rupee
PES	payments for environmental services
PMDS	Pre-Monsoon Dry Sowing
RySS	Rythu Sadhikara Samstha
SDGs	Sustainable Development Goals
SHGs	self-help groups
Tkcal	Terakilocalories
UBI	universal basic income

1. Introduction

In 2016, after a new decade of worsening agrarian crisis in India (Vaidyanathan, 2006), the southern Indian state of Andhra Pradesh (AP: 53 million inhabitants and 9.3 million famers in 2020) initiated the scaling of what came to be known first as Zero Budget Natural Farming (ZBNF) and was later renamed as the climate-resilient Andhra Pradesh Community-managed Natural Farming (APCNF: https://apcnf.in). This approach draws on the principles of regenerative agriculture (Harwood, 1983; Fukuoka, 1992, 2001; Rhodes, 2012) and is more broadly part of the "science, movement and practice" of agroecology (Wezel *et al.*, 2009).

Andhra Pradesh's natural farming focuses on healthy soils and landscape regeneration, highly diversified and synergistic crop/livestock/tree production, no pesticide or synthetic fertilizer use, indigenous seeds, limited tillage and local preparations using cow dung and urine to boost soil and plant health, pre-monsoon dry sowing (PMDS), high involvement and leadership of women's self-help groups (SHG), and farmer-centred learning (for more details on technical and institutional innovations, and bibliographic references, see Dorin, 2022). Less than five years later, as of April 2020, APCNF was already being practiced by around 700 000 farmers in Andhra Pradesh, with the hope that it would increase to 6 million farmers by 2027, on 6.2 million hectares (ha) of agricultural land.

This APCNF movement attracted the attention of other states in India, the central government, national and international institutions. It also raised controversies about natural farming's ability to feed a populous country such as India over the long run (Dorin, 2022). Overall, it called for exploring the long-term implications of such an option compared to a scenario of further intensification of conventional industrial agriculture and food production.

Our RySS-CIRAD-FAO foresight study "AgroEco2050" (2019–2022) attempts to address this latter challenge, combining scientific approaches with multi-stakeholder expertise. Co-constructed with policymakers of Andhra Pradesh and experts from various backgrounds across India (Figure 1, Annex 3), the study aims to explore the implications of two contrasted scenarios for agriculture, food, nature and welfare in Andhra Pradesh by 2050: conventional Industrial Agriculture (IA) versus Natural Farming or Agroecology (NF/AE). Such foresight in India by 2050 (Dorin, 2021) intends not only to support evidence-based policy decisions in the State, but also to be of prime interest for other Indian regions and worldwide. Overall, like the French foresight "Agrimonde" (Paillard *et al.*, 2014) it aims to contribute to national and international debates and researches on agroecology, and to demonstrate that an alternative future for food and agriculture is possible rather than the current trends, if we perceive it and work for it (Dorin and Joly, 2020).

Section 2 gives a few details of the foresight methodology followed. Section 3 provides a unique statistical overview of past evolutions, from the 1960s to 2019–20, in Andhra Pradesh but also at the All-India and world levels, for key dimensions of structural transformations: land use, population and employment, economic growth and labour productivity, food production and yield. These statistical series fed the qualitative storylines and quantitative assumptions for 2050 that are presented for each of the above dimensions in Section 4 (scenario of natural farming) and 5 (scenario of industrial agriculture). Section 6 compares the quantitative assumptions used for the two scenarios and present, and the sets of indicators computed by the Agribiom Lewisian Module. Section 7 concludes with the AgroEco2050 learning journey and provides policy-oriented suggestions to fully scale natural farming and agroecology in Andhra Pradesh.

Figure 1.
AgroEco2050 project kick-off meeting, Amaravati (Andhra Pradesh), 17 April 2019

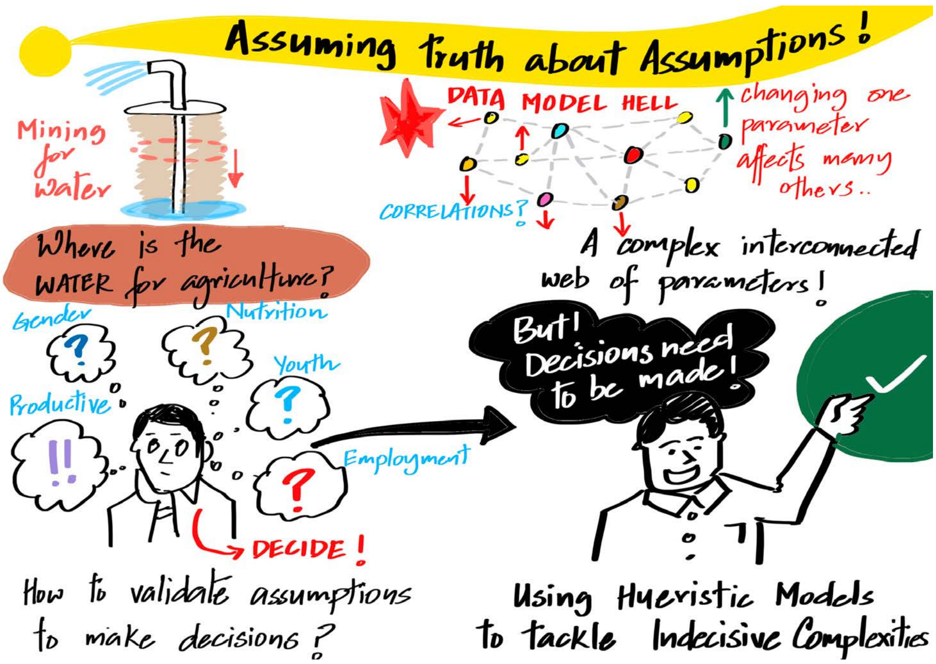
Source: Dorin, 2019

Figure 2.
Workshop Objectives & AgroEco2050

Source: Srinivas Mangipudi, 2022, New Delhi.

Figure 3.
Assuming Truth about Assumptions!

Source: Srinivas Mangipudi, 2022, New Delhi.



2. Revisiting the past and imagining the future with Agribiom

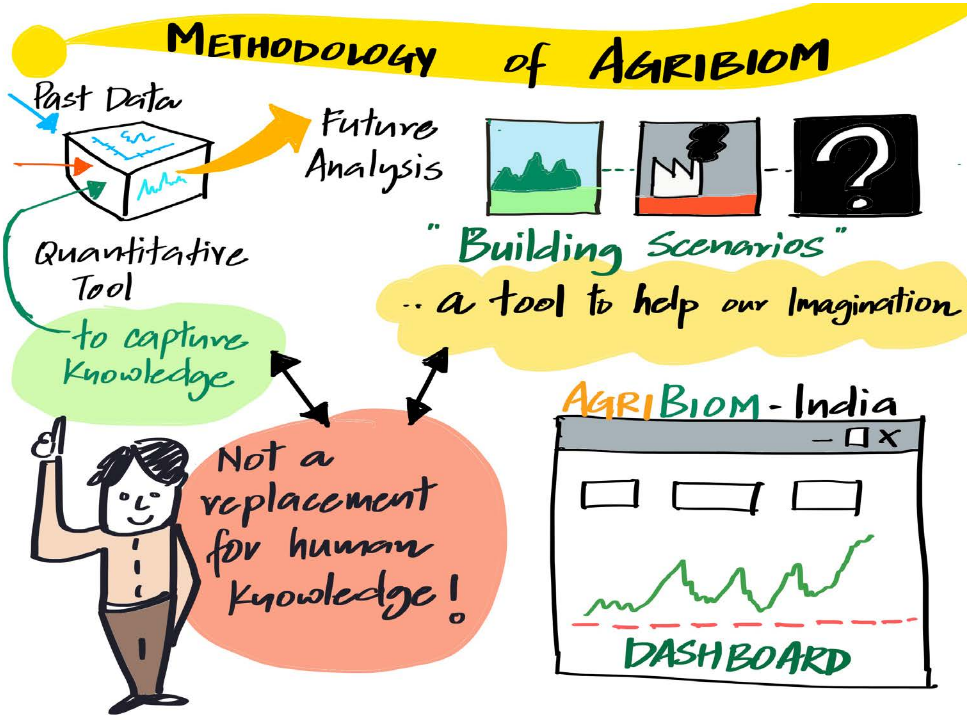


Figure 4
Methodology of Agribiom

Source: Srinivas Mangipudi, 2022, New Delhi.

2.1 THE AGRIBIOM MODEL AND DATA

Increasingly sophisticated bioeconomic models of agrifood production are now used to think of, or predict, future scenarios for the use of land and resources. As presented in Dorin and Joly (2020), these models are tools that are based on scientific evidence (available data, mathematical equations, theories) and are therefore considered as "truth machines" of the "real world" and its possible evolutions under x or y conditions. But they are also "tools of government" with many hidden political dimensions. Their "virtual realities" incorporate value judgments about today and the future that remain invisible and very difficult to challenge (they are embedded in what is called "sociotechnical regime" in Dorin, 2022). They now run thousands of equations with millions of data in a very impressive way, but they standardize functional forms and parameters in time and space, eliding for instance dependency on a historical path or territorial diversity and potentiality. In doing so, they blacklist the sociotechnical policy options such as those based on agroecology and local plant-animal-human synergies that are too complex to model. All in all, they remain unable to think outside the box, beyond the sociotechnical regime of industrial agriculture and food (Dorin, 2022). Within this box, they are designed for prediction and prescription rather than to support public debate, which is also a (comfortable) political stance.

In contrast, the Agribiom model is a tentative experiment in building an interactive "learning machine" (and not "machine learning"!), which is able to better capture and manage world complexity and specificities, by leaving room for a variety of scientific and stakeholder knowledge as well as public debate. Agribiom uses a dashboard that enables participants from various walks of life to test, debate and modify assumptions in real time collectively. It is expected that such models that attempt to hybrid existing scientific evidence with other forms of knowledge and assumptions about the world can unveil a few virtual realities, processes and actors that are today invisible in mainstream models, and assert interesting alternative visions of sustainable agrifood systems by 2050.

The ultimate goal of a quantitative tool or dashboard such as Agribiom is therefore to simultaneously improve knowledge, policymaking and democracy in the management of our production and consumption of biomass; and to help societies go where they wish to go, within terrestrial planetary boundaries. Such a relationship between science and politics is the hallmark of the French School of "La prospective" (Berger, 1964; Jouvenel, 1967; Godet, 1977), which also suggests that the best way to predict the future is to invent it [together].

To fulfil the above objectives, Agribiom was designed intentionally as a simple (but robust) quantitative model that can be a "companion" to expert interactions and discussions. Simplicity is considered a virtue in the philosophy of science, and the credibility of a model is conditioned by its ability to represent studied phenomena in simple ways, which also minimizes the risk of producing artefacts (Dorin and Joly, 2020). Hence Agribiom is not a "black box" nor a "magic box" able to indicate the optimal or most efficient solution thanks to large sets of mathematical equations based on specific assumptions (e.g. perfect competition, individual utility maximization, constant elasticity of substitution) as well as hundreds but very sensitive parameters (e.g. price or income elasticities) whose reliability is questionable both in space and time (Robinson *et al*., 2015: 17). To the contrary, with Agribiom, assumptions are made and debated by a group of heterogeneous stakeholders with diverse backgrounds and expertise; and their robustness and consistency are tested in real time using the interface, leading to further debates and final choices.

At the same time, Agribiom is data intensive for three main reasons. First, it is not focused on few large-scale industrial agricultural productions as most bioeconomic models today, but on all plant and animal biomasses for which statistical information can be found and then aggregated and balanced through specific metrics such as calories, proteins or market values. Second, this computation was done over a broad time range (several decades, since the 1960s) to observe, analyse, compare and discuss past structural transformations and path dependencies, from different viewpoints and different geographical angles. Third, all this is connected with the many other dimensions of food agricultural systems, from land uses to diets, human and animal populations, trade or GDP growth, for which statistics are also collected over the same period of time, then checked and annualized when required – a time consuming task especially with Indian data (see **Figure 6** and **Section 3** for additional details and illustrations of results; see also Patel *et al.*, 2022).

Figure 5 depicts the general architecture of "Agribiom-World" in 2007, with food (edible biomass) supply-use balances positioned in the middle of the figure. These balances are driven primarily (but not solely), on the one hand, by demand for food from plant, animal and aquatic origins, which depend, in turn, on populations and their specificities (size, preferences, level of wealth, public policies, etc.), and on the other hand, by more or less intensive production of edible biomass from crop land, pasture and water linked to land use. To this 2007 architecture was added in 2019 the "Agribiom Lewisian sub-Module" (ALM)[1] that can be used independently when time is short and the major issues to be discussed are employment, labour productivity, equity and path of structural transformation, as was the case with the AgroEco2050 foresight study in India.

Enabling such systemic views and discussions of agricultural and food systems in time and space, requires not only the use of specific metrics and indicators to synthetize the information and their evolution (such as annual yields in calories or proteins per hectare, or the "labour income gap" between farmers and non-farmers), but also a tool that helps visualize this information (sometimes with millions of

1 See more details on the Agribiom Lewisian sub-Module in the following sections

input data behind a simple curve) according to the units or the geographical scales (states or group of states, up to All-India in the case of "Agribiom-India") that the user group want to see and discuss. Such a visual interactive interface is usually lacking in mainstream models because its construction is very time-consuming and not academically rewarding. Agribiom was developed with Microsoft Access to allow: collective visualization and discussion of historical evolutions at various geographical scales; exploration and re-parametrization of econometric components (if any); interactive simulations; archiving and sharing of sets of quantitative results (scenarios or variants) along with their assumptions.

In the continuity of Agribiom-World, Agribiom-India[2] rigorously collects and combines a multiplicity of datasets from different sources to describe and analyse the agriculture and food of Indian states as never before. Here, considerable time was spent checking data for consistency, correcting or inferring them where necessary. When the data were not annual (e.g. five-year surveys), they were also annualized state-wise by linear interpolation. When

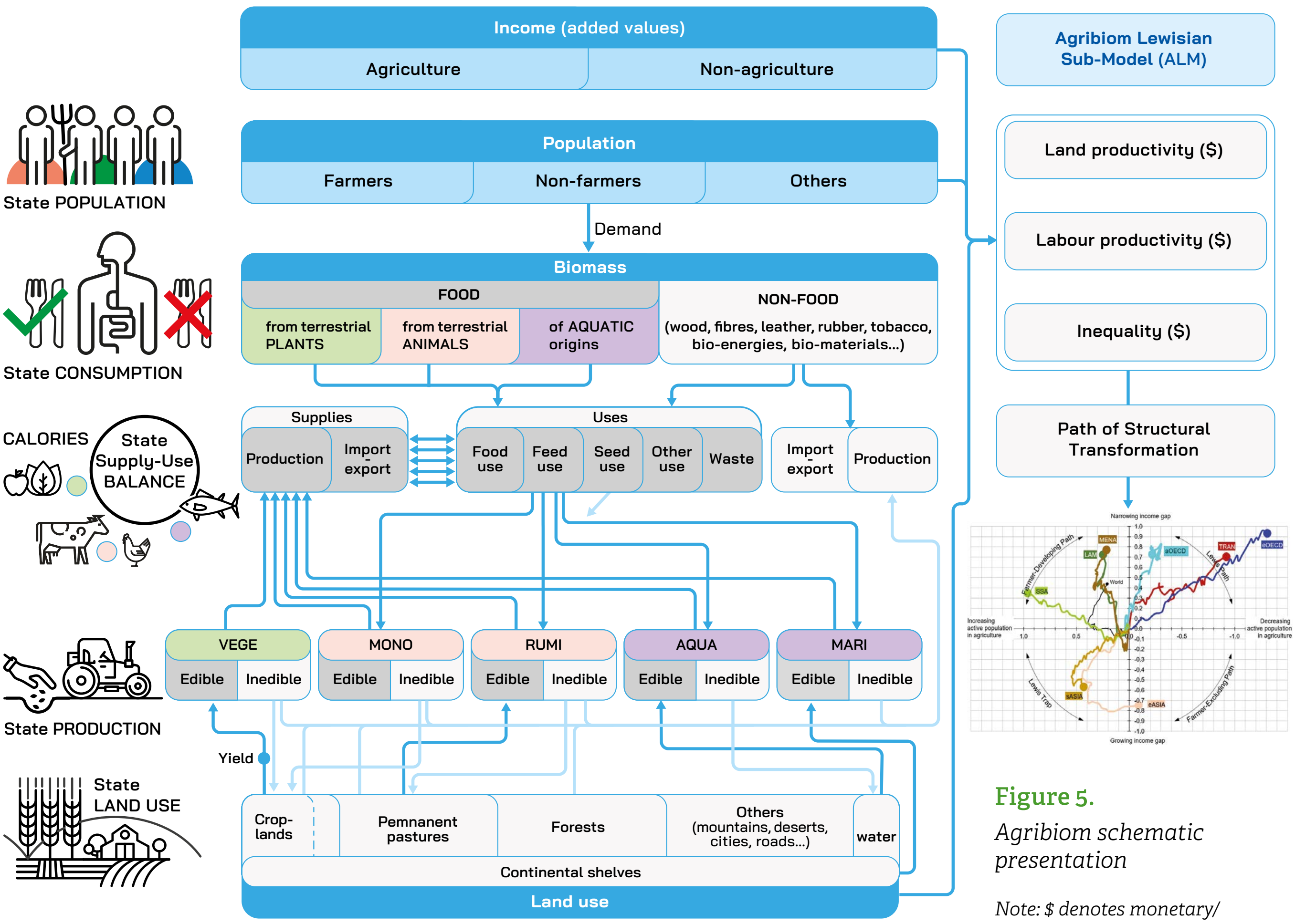


Figure 5.
Agribiom schematic presentation

Note: $ denotes monetary/ economic values.
Source: Dorin, 2023

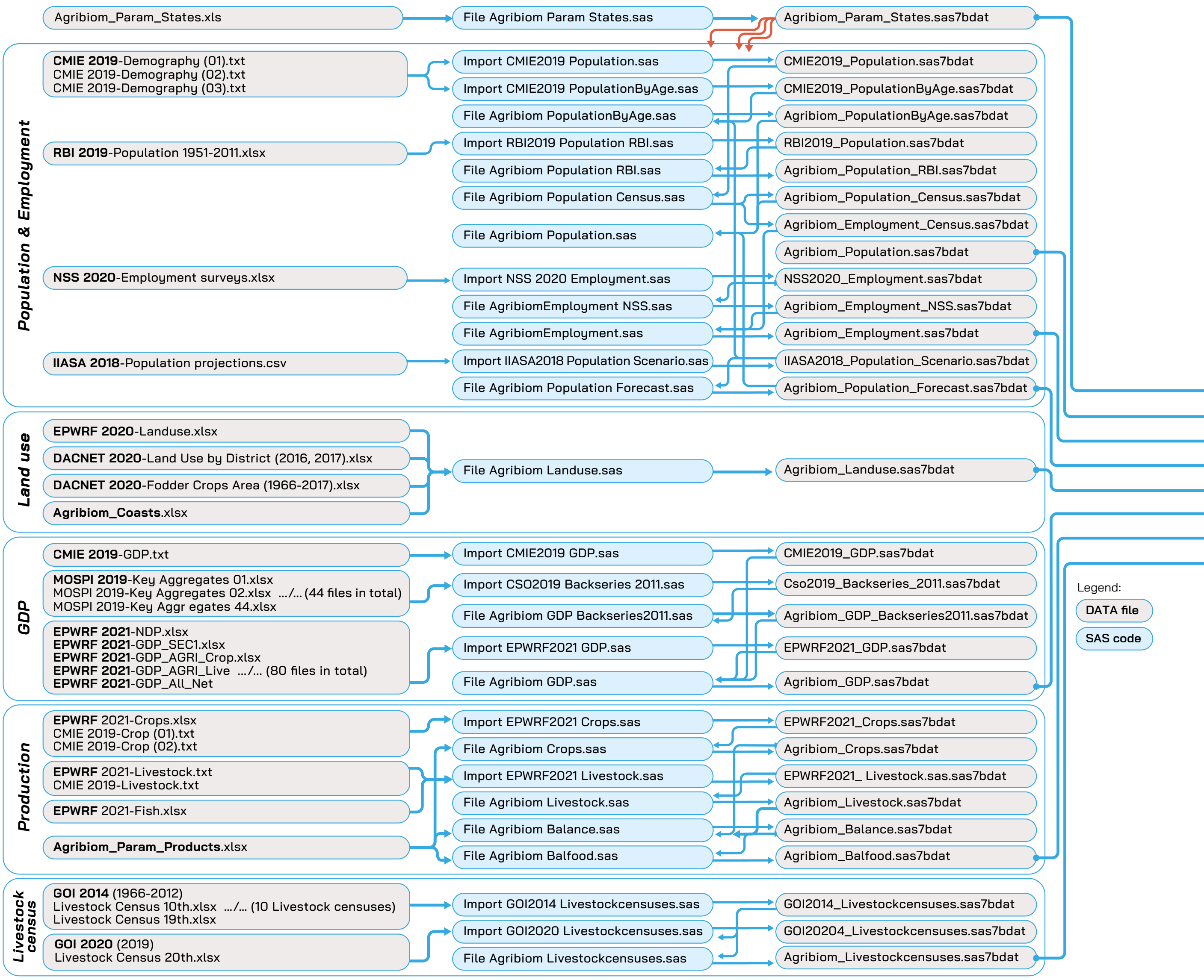
2 The construction of Agribiom-India began early 2019 with the support of two Indian research assistants, Jitumoni Deka (Agribiom interface with R-Shiny) and Vejendla T. Srinivasarao (data mining and management) hired by the RySS under the scientific direction of B. Dorin, and later replaced by Akshay Mahadevan and Anmol Sehgal. All are warmly thanked for their dedication and great contributions to the project, even if their contributions remain invisible to the public.

states bifurcated (e.g. Uttar Pradesh or Bihar in 2000), values for each bifurcated state were estimated prior to the bifurcation date. Once done, the historical data series generated by Agribiom (over almost 60 years, for All-India and by state) were transferred to the interface where additional codes were written to visualize the series, to instantly compute and display various new indicators, to finally allow users to enter and test their assumptions for future scenarios. An overview of the data used and the codes written for Agribiom-India is shown in **Figure 6**.

2.2 A MODEL RUNNING WITH AN EXPERT GROUP

In a nutshell, Agribiom is an interactive quantitative tool allowing a think-tank (gathering various stakeholders, knowledge and values) to revisit and explain together the past structural evolutions of an agrifood system, then to debate and test the quantitative consistency of assumptions made on long-term future scenarios of food and agriculture.

Figure 6. *Overview of file and code organization in Agribiom-India*

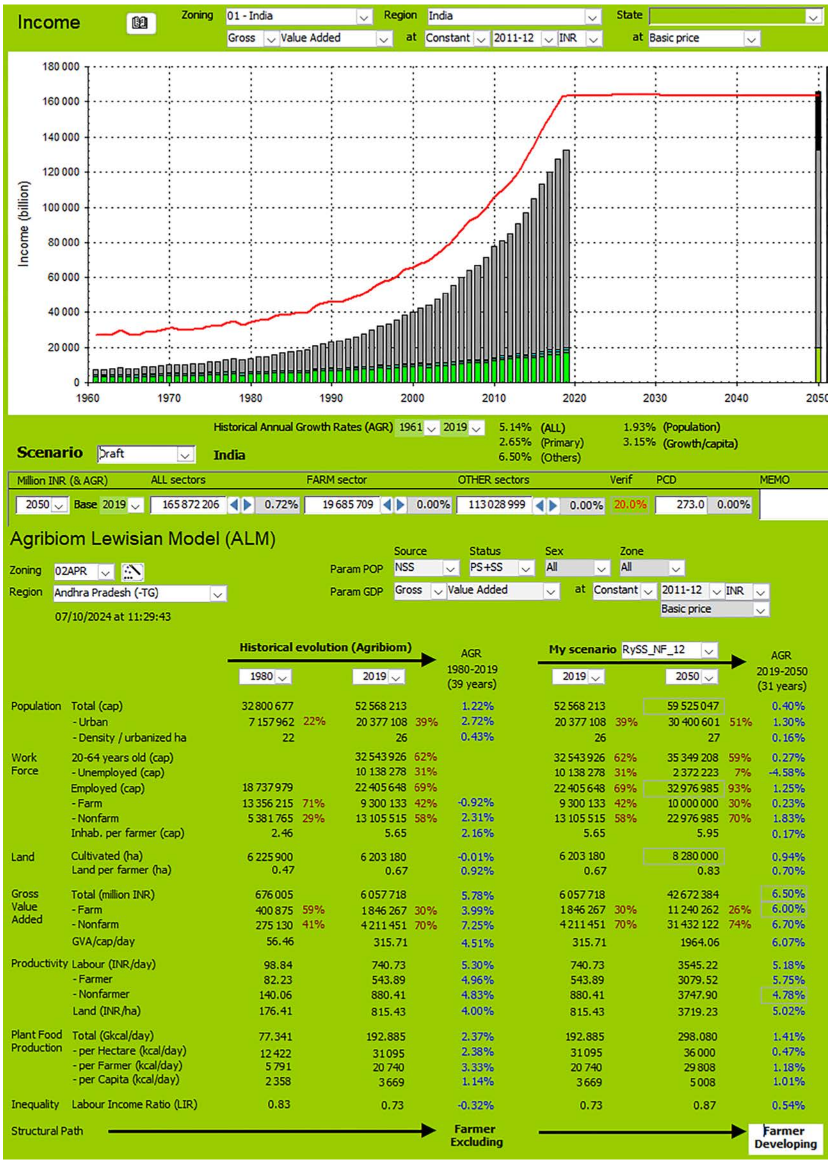


Source: Dorin, 2023

A multidisciplinary and multistakeholder think-tank, with a scenario-building exercise, and Agribiom model form together a three-component foresight platform (Figure 7), implementing an original articulation between production of knowledge and social dynamics. This foresight platform was first imagined and implemented by the global foresight "Agrimonde: Scenario and Challenges for Feeding the World in 2050" (Paillard *et al*., 2010, 2014) launched in 2006 (as Agribiom-World) by two French agronomic research centres, National Research Institute for Agriculture, France (INRA) and CIRAD.

At that time, the objective of the Agrimonde collective foresight was three-fold:

- to explore two contrasting possible futures of food and farming systems up to 2050;
- to design and debate orientations and strategies for INRA-CIRAD research agendas;
- to contribute to international debates on food, agriculture and the environment.



AGRIBIOM-India Model visual interface

(Microsoft Access and SQL code)

Source: Dorin, 2023

The Agrimonde think-tank gathered about thirty experts from different fields and institutions. These experts met almost once a month for over two years (between 2006 and 2008), in Paris or Montpellier. With Agribiom, they first revisited past structural evolutions, in a way that also allowed participants (agronomists, sociologists, economists, etc.) to learn to work together and build an atmosphere of trust. Then, Agribiom led discussions on future qualitative scenarios, translating the latter into quantitative assumptions, checking their overall quantitative consistency and their implications for the six world regions of the Millennium Ecosystem Assessment (MEA, 2005) chosen by the think-thank to carry out the analyses. It helped to create a common language, foster collective learning, stimulate imagination and overcome inconsistencies.

The present RySS-CIRAD-FAO AgroEco2050 foresight study, whose preparatory work started at the end of 2018, followed the same methodological approach (a three-component foresight platform: Figure 7) but with a version of Agribiom designed for India ("Agribiom-India"), a different think-tank, which met virtually and physically in India from 2020 to 2022, and different scenarios.

The initial objective of AgroEco2050 was to develop a comprehensive and credible long-term scenario for Natural Farming in Andhra Pradesh by exploring what impacts on farmers' livelihood, land use, productivity, nutrition, public finance and other aspects could be expected by 2050 if Andhra Pradesh were to move to a "Natural Farming at scale" Agroecological scenario (called the "NF" or "AE" scenario), compared to the impacts of a "deepening conventional agriculture" scenario (called the "Industrial Agriculture" or "IA" scenario). Through this foresight, the aim was to contribute to state, national and international research and debates on agroecology.

During the official kick-off meeting for the project, which took place in May 2019 in Amaravati at the Andhra Pradesh Secretariat, it was agreed to form a multistakeholders Expert Group (EG) of a maximum of 40 people.[3] Such a group would, as far as possible, gather together various stakeholders (scientists of various disciplines, policymakers, farmers' representatives, industrialists, civil society) with contrasting views, a goal that could only be filled partially. It was also planned to gather this EG through at least four in-person workshops (of 3 to 5 days each) with Agribiom, since it was deemed difficult for participants to interact with Agribiom remotely and without live direct interactions between participants. Unfortunately, as a result of the national polemic concerning Zero Budget Natural Farming (ZBNF), which started in September 2019 (Dorin, 2022: 9–11), then the COVID-19 pandemic from March 2020 for two years, none of these workshops could be organized. Instead, seven online workshops of half-day each were organized to prepare the ground and advance the work, between September 2020 and June 2021 (see dates and agenda in Annex 4

During these online workshops, the foresight project and its methodology were presented, the EG members shared their vision through individual presentations, and the group started brainstorming collectively on the two contrasting future scenarios we wanted to imagine and compare. The first in-person workshop took place in 2021 in Anantapur (South of Andhra Pradesh). During this five-day workshop (including a field trip on the first day), not all official EG members could join, or stay throughout the five days, but others replaced them (see list of participants and agenda in Annex 4.2). The Agribiom Lewisian Model (ALM) was ready and could be run with its focus on land use, population and employment, growth and farm–non-farm labour productivity (see more details on ALM in the next section). The two contrasted storylines (IA and NF/AE scenarios) could therefore be further

3 A group of over 40 people becomes hard to manage for participatory processes. This is one limit of the method as it limits the number of people who can be directly involved; however, the foresight results can later be debated in multiple fora (local, national and international), as it was the case with Agrimonde. The final list of participants who accepted to join the EG, and to participate in all its meetings (an important condition that was unfortunately unable to be followed by all), is given in the Annex 3.2.

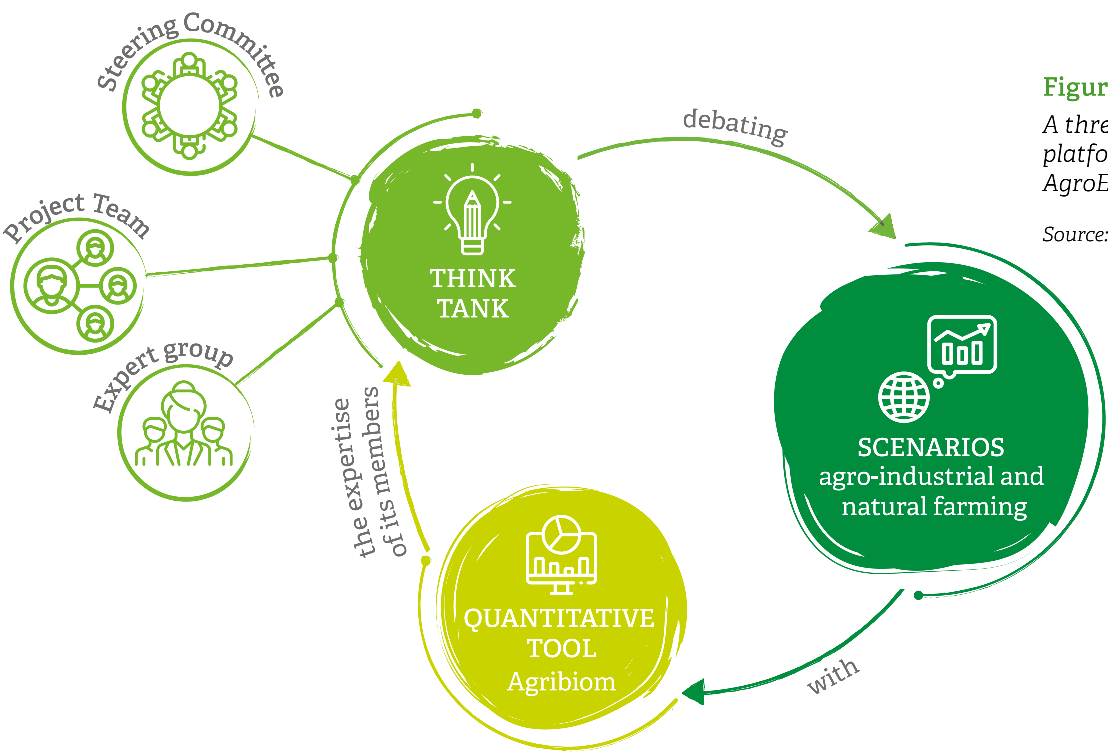


Figure 7
A three-component platform for the foresight AgroEco2050

Source: Dorin, 2023.

explored, discussed and converted into quantitative results for 2050 thanks to consistent expert assumptions on several parameters. These draft quantitative scenarios were then re-visited, re-discussed and slightly revised during a "validation workshop" of the Expert Group which took place in November 2022 at Andhra Bhawan in New Delhi (see list of participants and agenda in Annex 4.3). This workshop also introduced and discussed some new estimates related to calorie food production and public support to agriculture, the reduction of income inequalities or environmental services.

On the other hand, several initial objectives of AgroEco2050 could not be implemented, with regard to the composition and functioning of the EG, but also to the dimensions it was supposed to invest and discuss, in particular human and animal diets, trade and overall supply-utilization accounts in calories and macro-nutriments. This was because of the unfortunate events mentioned above, but also to delays in obtaining consistent annual Indian data over the past decades in order to deduct any missing past estimates or modelling framework for the future, especially for animal feed.

Only a small fraction of Agribiom-India's data and modelling has, therefore, been used and valued during the workshops. However, the version of the model still allowed for rich open discussions between different academics and practitioners, and undoubtedly, permitted them to clarify and quantify the most important dimensions of each scenario. All in all, as with the Consultative Group on International Agricultural Research (CGIAR) toolkit "Foresight for Future Planning" (Chesterman and Neely, 2021), Agribiom helped participants to apply foresight tools and methods for innovative research in development prioritization, to assist them in strategic planning and policy formulation for relevant transformation in agriculture and food systems.

2.3 THINKING AND GUIDING PATHS OF STRUCTURAL TRANSFORMATION

During the in-person September 2021 workshop in Anantapur, participants first collectively revisited past structural evolutions through the lens of Agribiom. They then discussed the relevance but also the limits of certain statistics, and were invited to propose quantitative values for 2050, which they believed would be most consistent with the vision and rationale of each scenario in terms of land use, population, employment and GDP.

After hours of lively discussions in each of these areas, supported by presentations or short videos of other visioning exercises, the Agribiom Lewisian sub-Module (ALM) was run. This Agribiom sub-Module computes different indicators based on past data and future assumptions on land use, employment and economic growth, to help verify that scenario assumptions are consistent with its qualitative story line and rationality. When inconsistencies are found, as was the case during the last day of the workshop, certain assumptions are modified live – and with additional discussion – to better fit the qualitative story line of the scenario and ensure its quantitative consistency and credibility. For instance, if the assumptions made by participants led to widening the income gap between farmers and non-farmers whereas more equity was a key principle of the AE scenario, some assumptions (on employment, economic growth, land use) need to be revised.

The ALM also compute the structural "Lewisian" paths followed in each scenario from its base year to its end year (2019–2050 in AgroEco2050, i.e. over 31 years), and allows for comparison of the envisioned trajectory with past trajectories (e.g. 1980–2019) whatever the base year and end years chosen (live computations). These structural "Lewisian" paths are explained and illustrated at the global level in Dorin *et al.* (2013), but also at the level of the Indian States in Patel *et al.* (2022) over the past decades.

Four paths are delineated with two variables (**Table 2**):

- The annual cumulative growth in the number of workers (self-employed or not) in agriculture (L_a), which is a proxy of the nature of agricultural growth (i.e. labour-intensive growth *versus* land- and capital-intensive growth through motor-mechanization).
- The annual cumulative growth of the farm–non-farm income gap (i.e. the difference in average income between farmers and those employed in other sectors) here called "Labour Income Ratio" or "LIR". This LIR was considered the most relevant among the three indicators found in the academic literature (Table 1).[4] It combines labour (either total L or in agriculture L_a) and value added (either total Y or in agriculture Y_a).

The four paths are successively named "Lewis Path" (LP), "Lewis Trap" (LT), "Farmer Excluding" (FE) and "Farmer Developing" (FD) paths (Dorin *et al.*, 2013). The "Lewis Path" represents the canonical model in economics of "modern economic growth" (Kuznets, 1966) or "Structural Transformation" (Chenery and Srinivasan, 1998). It was followed by countries in the Organization for Economic Co-operation and Development (OECD) from the 1960s, until what is now called a "World Without Agriculture" (Timmer, 2009) where agriculture represents no more than 2–3 percent of employment and 2–3 percent of GDP thanks to fewer and fewer but larger and larger mechanized industrial farms.

In this path or model, labour incomes converge between farmers and non-farmers as outgoing farmers are replaced by machines and robots that boost labour productivity of the remaining farmers. In other words, in this path, agricultural labour productivity grows faster than the demand for agricultural products and also faster than the average labour productivity (see mathematics in Table 2) thanks to machines and much fossil energy and other

4 We chose the LIR to normalize the gap between 0 and 1 and to avoid an overestimation of inequality within a population when a sector (agriculture or non-agriculture) has a large income gap with another but accounts for a very small percentage of the active population.

rare resources to manufacture and run them. We named this pathway "Lewis Path" as it looks like the shift from the "subsistence sector" to the "capitalist sector" in Lewis' iconic model (Lewis, 1954).

In the path we call "Lewis Trap", the income differential between farmers and non-farmers widens and the agricultural workforce increases. Farmers' labour productivity increases less rapidly than agricultural output and average labour productivity. This is the exact opposite of the Lewis Path. Unless new arable land becomes available through deforestation, or many farmers migrate to other domestic or foreign economic sectors, average acreage per farmer decreases, thereby diminishing the possibility of increasing labour productivity through large-scale motorized mechanization. We view this Lewis Trap as a path of structural transformation as, even if the agricultural workforce stabilizes or decreases in numbers in the future, the average land endowment per farmer may remain extremely low for decades or even centuries.

In the "Farmer Excluding" path, the number of farmers decreases but the income gap with non-agricultural workers widens (farmers become fewer and poorer in relation to other workers), while in the "Farmer Developing" path, farm and non-farm labour incomes converge while the number of farmers increases. In this FD path, high growth in demand for agricultural products pulls farmers wages up faster than average. The interpretation of this path is not univocally positive as, if agricultural demand is driven by the foreign rather than the domestic market, it may be consistent with growing urban poverty.

These four paths of structural transformation make it possible to evidence and explain the limit of the canonical model of "modern economic growth" in many regions of the world, with past data (e.g. Dorin, 2022) or with future scenarios (e.g. Dorin, 2017). Figure 8 (ALM screenshot) illustrates the All-India 2007–2050 baseline scenario presented in Dorin *et al.* (2013), using some assumptions and results of Shukla and Dhar's (2011) computable general equilibrium model used for long-run projections of the energy sector. In this baseline scenario, India falls in a "Farmer Excluding" path, where farmers are fewer (217 million in 2050 against 256 million in 2007) but also much poorer compared to the rest of the working population (the farm–non-farm Labour Income Ratio is divided by 3 compared to 2007, indicating a further increase in income inequalities compared to 2007 when they were already high). At the same time, the average farm labour productivity increases by 3.2 percent annually. But it is far less than the 5.2 percent increase for the non-farm workers.

Table 1. *Indicators of cross-sectoral income gap between agriculture and non-agriculture*

Indicator	Formula	Example of use
(1) Agricultural Productivity Gap (APG)	$(Y_{na}/L_{na}) / (Y_a/L_a)$	Gollin *et al.* (2014)
(2) Labour Income Gap (LIG)	$(Y_a/Y) - (L_a/L)$	Timmer (2009)
(3) Labour Income Ratio (LIR)	$(Y_a/Y) / (L_a/L)$	Dorin *et al.* (2013) based on Hayami and Godo (2004)

Source: Dorin, 2023.

Table 2

Typology of structural transformation paths

Source: Dorin, Hourcade, Benoit-Cattin. 2013. A World without Farmers? The Lewis Path Revisited [CIRED Working Paper 47]. Nogent sur Marne, CIRED. https://hal.science/hal-00866413

			Employment in agriculture: Increasing	Employment in agriculture: Decreasing
			$\dot{L}_a/L_a > 0$ $(\dot{\theta}_a/\theta_a < \dot{Y}_a/Y_a)$	$\dot{L}_a/L_a < 0$ $(\dot{\theta}_a/\theta_a > \dot{Y}_a/Y_a)$
Labour productivity gap between farmers and non-farmers	Narrowing	$\dot{LIR}/LIR > 0$ $(\dot{\theta}_a/\theta_a > \dot{\theta}/\theta)$	(A) Farmer-developing $\dot{Y}_a/Y_a > \dot{\theta}_a/\theta_a > \dot{\theta}/\theta$	(B) Lewis Path $\dot{\theta}_a/\theta_a > \max(\dot{Y}_a/Y_a, \dot{\theta}/\theta)$
	Growing	$\dot{LIR}/LIR < 0$ $(\dot{\theta}_a/\theta_a > \dot{\theta}/\theta)$	(C) Lewis Trap $\dot{\theta}_a/\theta_a < \min(\dot{Y}_a/Y_a, \dot{\theta}/\theta)$	(D) Farmer-excluding $\dot{\theta}/\theta > \dot{\theta}_a/\dot{\theta}_a > \dot{Y}_a/Y_a$

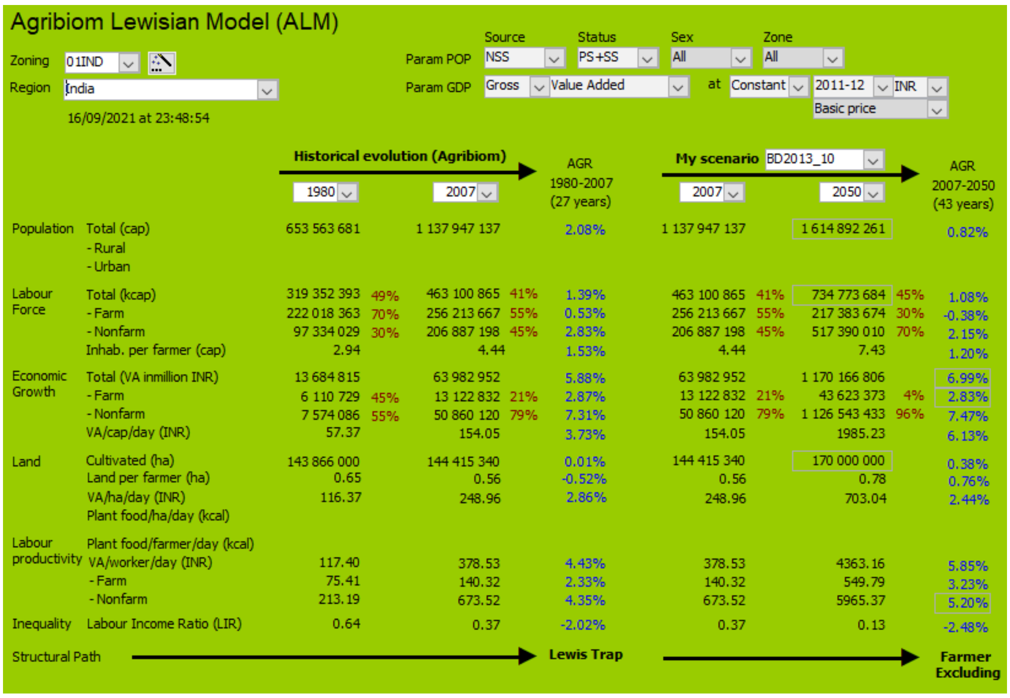
- In path A or "Farmer Developing" path, farm and non-farm labour incomes converge (LIR→1) while the number of farmers increases ($\dot{L}_a/L_a > 0$). High growth in demand for agricultural products (Y_a) pulls farmers wages up (ϑ_a) faster than average (ϑ).
- In path B or "Lewis Path", labour incomes also converge but the agricultural workforce decreases in absolute numbers. Outgoing farmers can be replaced by machines and robots that will boost labour productivity (ϑ_a): the latter grows faster than demand for agricultural products Y_a and also faster than average labour productivity (ϑ).
- In path C or "Lewis Trap", the income differential widens ($\dot{LIR}/LIR < 0$) and the agricultural workforce increases. Farmers' labour productivity (ϑ_a) increases less rapidly than agricultural output (Y_a) and average labour productivity (ϑ).
- In path D or "Farmer-Excluding" path, the number of farmers decreases and the income gap with non-agricultural workers widens. This is a Farmer-Excluding path since farmers become fewer and poorer in relation to other workers.

Figure 8

A 2007–2050 scenario for all-India

Note: AGR = Annual growth rate

Source: Dorin's Agribiom Lewisian model, with data from Dorin, Hourcade, Benoit-Cattin. 2013. A World without Farmers? The Lewis Path Revisited [CIRED Working Paper 47]. Nogent sur Marne, CIRED. https://hal.science/hal-00866413


Agribiom Lewisian Model (ALM)

Zoning 01IND — Region India — 16/09/2021 at 23:48:54

Param POP: Source NSS; Status PS+SS; Sex All; Zone All

Param GDP: Gross; Value Added; at Constant; 2011-12; INR; Basic price

Historical evolution (Agribiom) — My scenario BD2013_10

		1980		2007		AGR 1980-2007 (27 years)	2007		2050		AGR 2007-2050 (43 years)
Population	Total (cap)	653 563 681		1 137 947 137		2.08%	1 137 947 137		1 614 892 261		0.82%
	- Rural										
	- Urban										
Labour Force	Total (kcap)	319 352 393	49%	463 100 865	41%	1.39%	463 100 865	41%	734 773 684	45%	1.08%
	- Farm	222 018 363	70%	256 213 667	55%	0.53%	256 213 667	55%	217 383 674	30%	-0.38%
	- Nonfarm	97 334 029	30%	206 887 198	45%	2.83%	206 887 198	45%	517 390 010	70%	2.15%
	Inhab. per farmer (cap)	2.94		4.44		1.53%	4.44		7.43		1.20%
Economic Growth	Total (VA inmillion INR)	13 684 815		63 982 952		5.88%	63 982 952		1 170 166 806		6.99%
	- Farm	6 110 729	45%	13 122 832	21%	2.87%	13 122 832	21%	43 623 373	4%	2.83%
	- Nonfarm	7 574 086	55%	50 860 120	79%	7.31%	50 860 120	79%	1 126 543 433	96%	7.47%
	VA/cap/day (INR)	57.37		154.05		3.73%	154.05		1985.23		6.13%
Land	Cultivated (ha)	143 866 000		144 415 340		0.01%	144 415 340		170 000 000		0.38%
	Land per farmer (ha)	0.65		0.56		-0.52%	0.56		0.78		0.76%
	VA/ha/day (INR)	116.37		248.96		2.86%	248.96		703.04		2.44%
	Plant food/ha/day (kcal)										
Labour productivity	Plant food/farmer/day (kcal)										
	VA/worker/day (INR)	117.40		378.53		4.43%	378.53		4363.16		5.85%
	- Farm	75.41		140.32		2.33%	140.32		549.79		3.23%
	- Nonfarm	213.19		673.52		4.35%	673.52		5965.37		5.20%
Inequality	Labour Income Ratio (LIR)	0.64		0.37		-2.02%	0.37		0.13		-2.48%
Structural Path						Lewis Trap					Farmer Excluding

3. Overview of past structural transformations (1960–2019)

In this section, we offer a unique statistical overview of past structural transformations over more than half a century (1960s–2019), from the world level down to India and then the state of Andhra Pradesh, in order to better understand how the latter has evolved and distinguished itself (or not) from its evolving environment. The estimates presented are those generated and used by Agribiom and its Lewisan Model/Module (ALM). They cover and interlink four general areas of interest: land use, population and employment, economic growth and inequality, food production and yields. Estimates were generated from available international statistics at the country level with Agribiom-World, and from national statistics at the Indian States level with Agribiom-India. Data sources and statistical processing for Agribiom-India are detailed in Annex 1. As we will see with the crossroads geographical entity "India" (noted below "India" with Agribiom-World, and "All-India" with Agribiom-India), statistical categories or values may differ between national sources and international sources, which serves as a reminder here that all statistical estimates remain human-made objects rather than reality itself, and that the orders of magnitude and the direction of change over time, rather than the absolute values at any given point in time, are the real artefacts to trust here.

3.1 LAND USE

The way we use the surface of our finite planet is a fundamental dimension of our human activities and has vast consequences in many fields, including climate change. The **total world surface** is about **510 million km², with 71 percent under water** (including "continental shelves" where we fish) and the rest (including ice cover) is **terrestrial land of 149 million km², with 2 percent only in India**.

Figure 9 generated by Agribiom-World with old and recent FAOSTAT (2022) data, displays the evolution for almost 60 years (1961-2019) of World and India's land uses. Compared to the world figures, India displays at least three specificities:

- about **half of India's terrestrial area is under agricultural use** (12 percent at the word level), which also corresponds to what Fischer *et al.* (2002) estimated as the surface "very suitable", "suitable" or "moderately suitable" for crop cultivation in India; in other words, India cultivates **almost 100 percent of its cultivable land** (96 percent in 2019), while globally it is half (47 percent, with some of these lands still under forests);
- over **40 percent of these cropped lands are irrigated** against 21 percent at the world level (including India);
- the Indian surface under **pastures** (land under permanent meadows and pastures, including savannas) is very low and represents **6 percent of the agricultural surface** (crops + pastures) while it is 67 percent at the global level.

Obviously, India is a **land-squeezed country** to feed its population: its **cropland** represented 0.12 ha per inhabitant and **0.85 ha per farmer** on average in 2019, while these figures were 0.20 and 1.77 respectively at the world level (Figure 10), with large variations (e.g. with Canada: 1.0 and 132 ha respectively).

Figure 11 and following, generated by Agribiom-India (see Annex 9.1.1 for data sources and management), display similar evolutions than above for All-India and Andhra Pradesh, with more accuracy and details except for the Indian missing category "Water" (in FAO: area under fresh water, such as river, lake or canals). Compared to All-India figures, **Andhra Pradesh has**:

- a smaller share of cultivated areas but **more fallow, urbanized and barren lands** (Figure 11);
- **0.67 ha of (net) cropland per farmer** against 0.76 ha for All-India in 2019 with the National Statistical Office (NSO) (2020) data on employment in agriculture and allied activities, which is almost the level of 1973 after a sharp decline till the 2000s (Figure 12);

- a **crop intensity that increased to 123** in 2019, but which remains below the Indian average of 141 (**Figure 13**);
- **45 percent of cultivated area under irrigation** in 2019 (the Indian average is 47 percent), with a share of canals and tanks well above the Indian average even if these two means have decreased over time to give way to tube wells running on diesel or electricity (**Figure 14**).

Figure 9

Land use – world and India, 1961–2020 (hectares)

Source: Dorin, 2023.

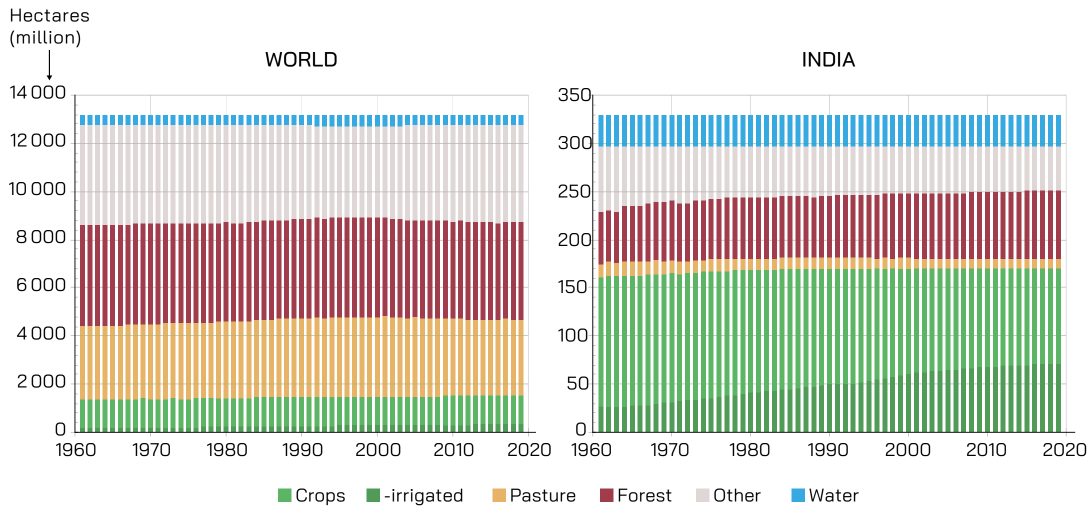


Figure 10

Cropland availability – world and India, 1961–2020 (hectare per farmer or per inhabitant)

Source: Dorin, 2023.

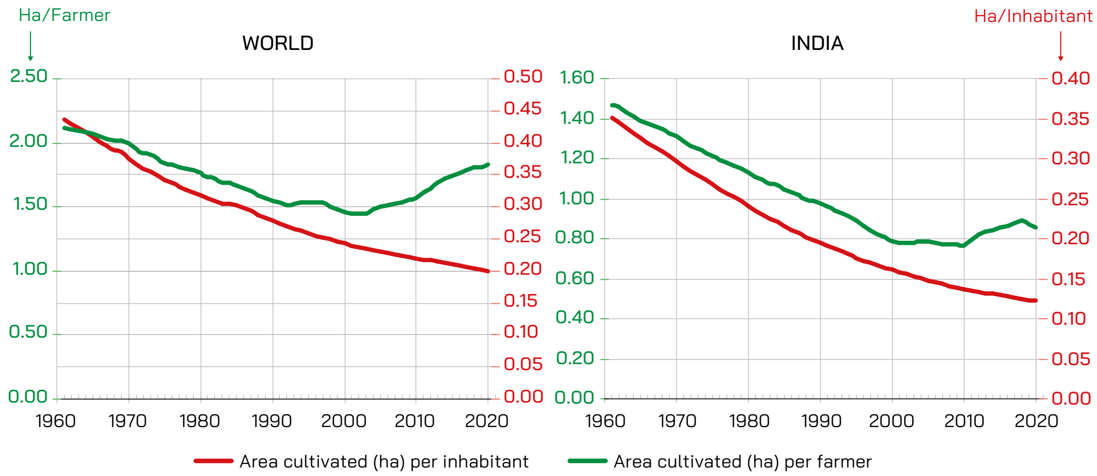
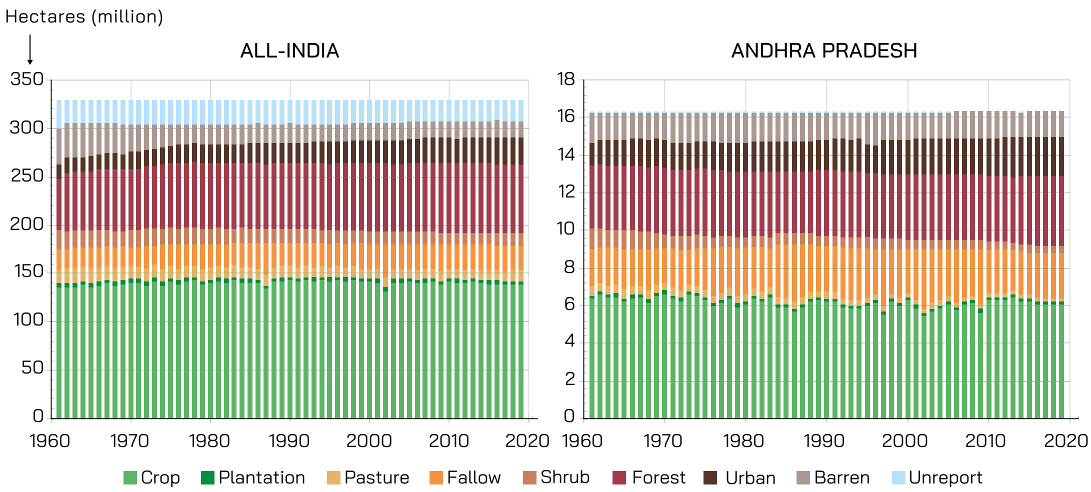


Figure 11

Land use – all-India and Andhra Pradesh, 1961–2019 (hectares)

Source: Dorin, 2023.



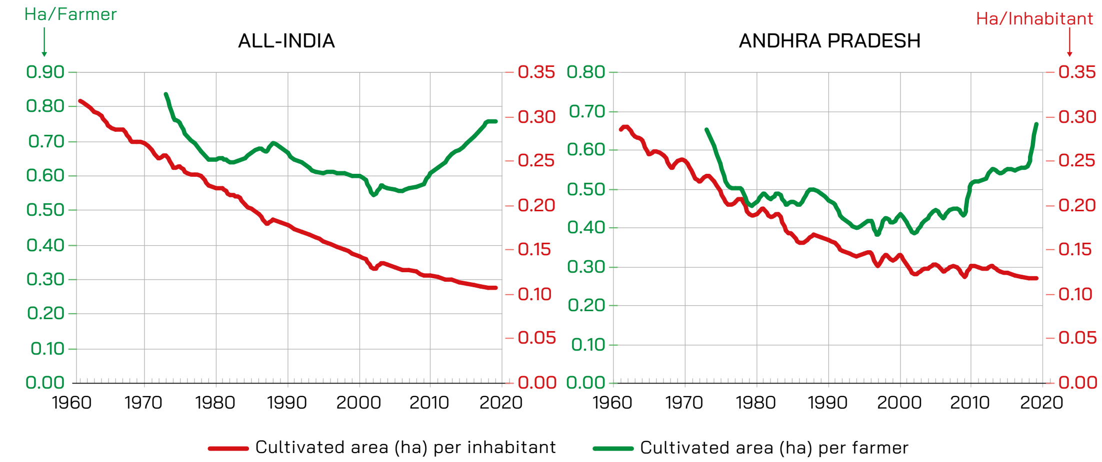


Figure 12

Cropland availability – all-India and Andhra Pradesh, 1961–2019 (hectare per farmer or per inhabitant)

Source: Dorin, 2023.

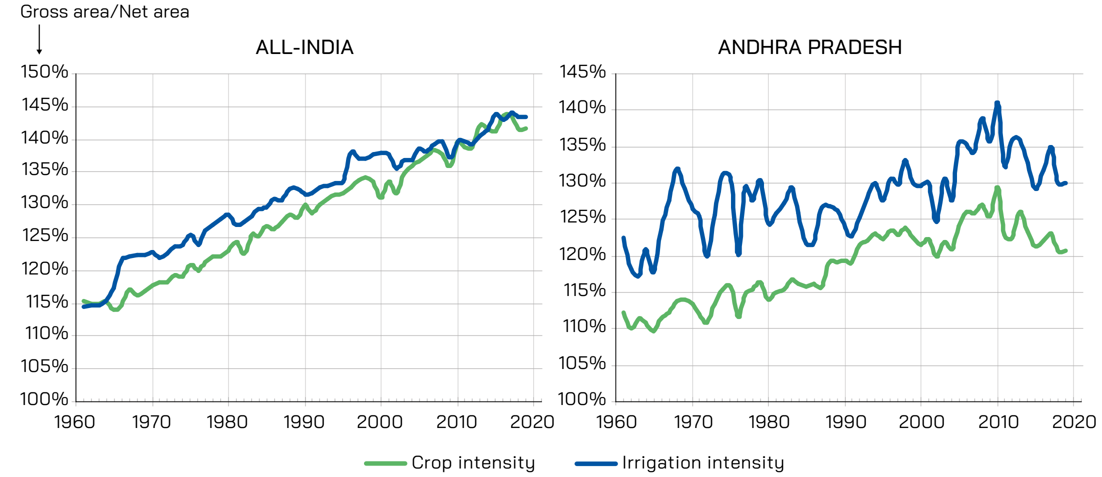


Figure 13

Crop intensity – all-India and Andhra Pradesh, 1961–2019 (gross area/net area)

Source: Dorin, 2023.

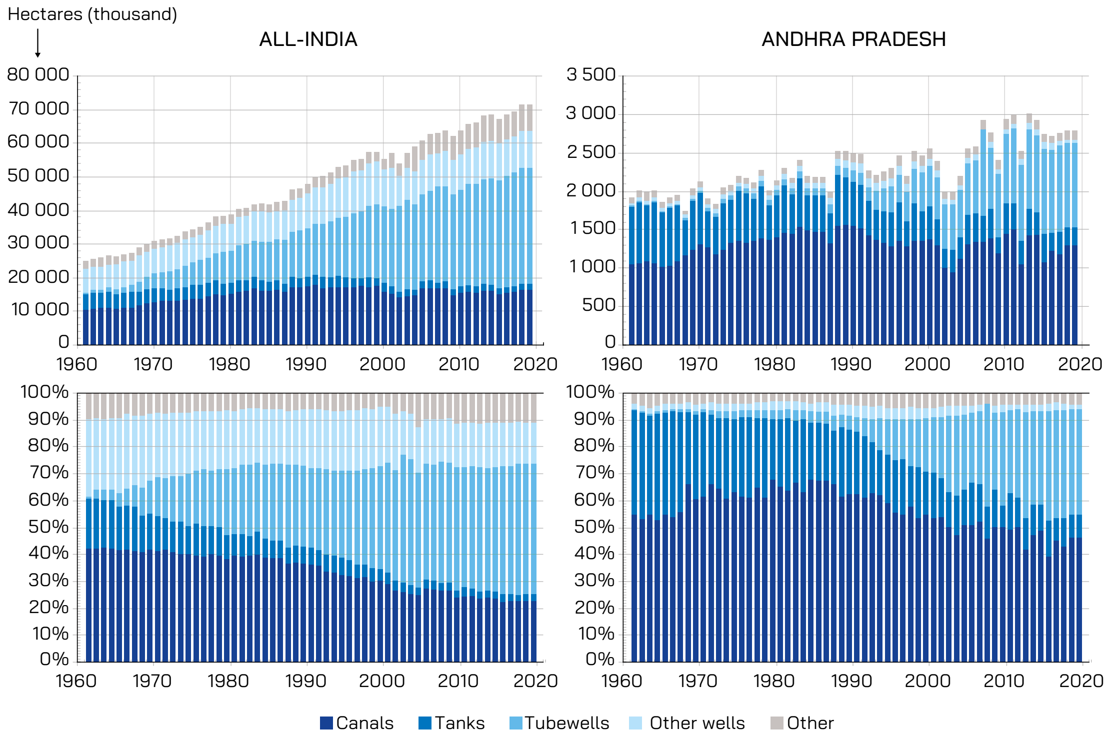


Figure 14

Irrigation – all-India and Andhra Pradesh, 1961–2019 (hectares and share by category)

Source: Dorin, 2023.

3.2 POPULATION AND EMPLOYMENT

The **global human population** has increased at an unprecedented pace since the Second World War. It was **7.9 billion in 2021, 3.2 more than in 1951**, and it should continue to rise throughout the twenty-first century, to reach **9.7 billion in 2050** and 10.35 billion in 2100 according to the "medium fertility" scenario of the 2022 population prospects of the United Nations (UN, 2022).[5]

While the human population of most OECD countries is aging, this is not the case for the Asian and African continents in particular, where the young population continues to increase sharply. This is particularly the case in **India**, which represented **18 percent of the world population in 2021** against 14 percent in 1951. This Indian population exceeded that of China in 2023 and is expected to peak at 1.697 billion in 2063 according to the 2022 prospects of the United Nations (scenario "medium fertility"). The Indian population will need to have "physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996), and therefore also have access to decent employment and income to be food secure.

Figure 15, generated by Agribiom-World with United Nations (2022), International Labour Organization (ILO) (2023) and old FAO data, displays evolutions over 60 years (1960–2020) of World and India's populations as well as their employment by economic activity. From these estimates, we can note at least the following features:

- in 2019 (pre-COVID-19), amongst a world population of 7.765 billion, almost **3.273 billion** (42 percent) **were employed worldwide**, which represented **74 percent of the 20 to 64 year-olds** (or 26 percent of "unemployment")[6] while it was only 59 percent in India (or 41 percent of "unemployment"), a very low figure which has worsened since the mid-2000s with the withdrawal of women from the so-called "active life" (Mehrotra and Sinha, 2017).;
- in 2019, **worldwide farmers** were estimated at **863 million**, or **26 percent of the world active** population;
- 23 percent or **194 million farmers were in India**, which represented **41 percent of the Indian active population**;
- in the world as in India, the **number of farmers has increased in absolute numbers until the mid-2000s, then started to decline**; so we can suspect, as shown elsewhere (Dorin *et al*., 2013; Dorin, 2017, 2022), that most farmers around the world have seen their land availability decrease from one generation to another since 1961, unlike in OECD countries where the increase in the size of the farms and their robotization has been the main driving force behind their increase in farm labour productivity and income.
- While **more than half of the world's population became urban in 2007** according to the World Urbanization Prospects of the United Nations (UN, 2018), this is not expected to happen in **India** until **2046** (Figure 18).
- Figure 16 and following, generated by Agribiom-India (see Annex 1.2 for data sources and management), display very similar estimates and evolutions over 1961–2019, with two slight specificities of **Andhra Pradesh** compared to All-India:
- a **slightly better rate of employment** despite a similar **stagnation of the employed persons since the mid-2000s** (while the populations continue to grow in both cases) (Figure 16);

5 The projection for "high fertility" is 14.8 billion in 2100, and 7.0 billion for "low fertility" with a peak of 8.9 billion in 2053

6 According to the standard usage, those who are in the "working age group" (say 20–64 as chosen in this study) includes three groups, namely those who are working (i.e. employed), those who are "willing to work and seeking work" (unemployed) and those who are not seeking work. Because of the problems in differentiating and estimating "willing to work" and "not will to work", especially in the future, all 20–64 years who are without employment, whether they are willing/able to work or not, are treated as "unemployed" in this study. Our "unemployment rate" (1 – employed/20–64) is therefore higher than that currently measured and displayed by statistical organizations.

- a **slower decline in jobs in agriculture** and allied activities (Figure 17); with **9.3 million farmers in 2019**, Andhra represented 5–6 percent of the Indian population considered to be employed in agriculture.

Demographic projections used in this study are those made by the International Institute for Applied Systems Analysis (IIASA) (KC *et al.*, 2018), from 2011 (last published Indian census) till 2100 (every five years), for each Indian States, which is unique. In 2021, IIASA's projection for All-India is 3.7 percent lower (47 million people) than those of the United Nation (United Nations, 2022), 0.4 percent lower (6 million people) for 2050, and 7.2 percent higher for 2100 (110 million people) (Figure 19, Figure 20).

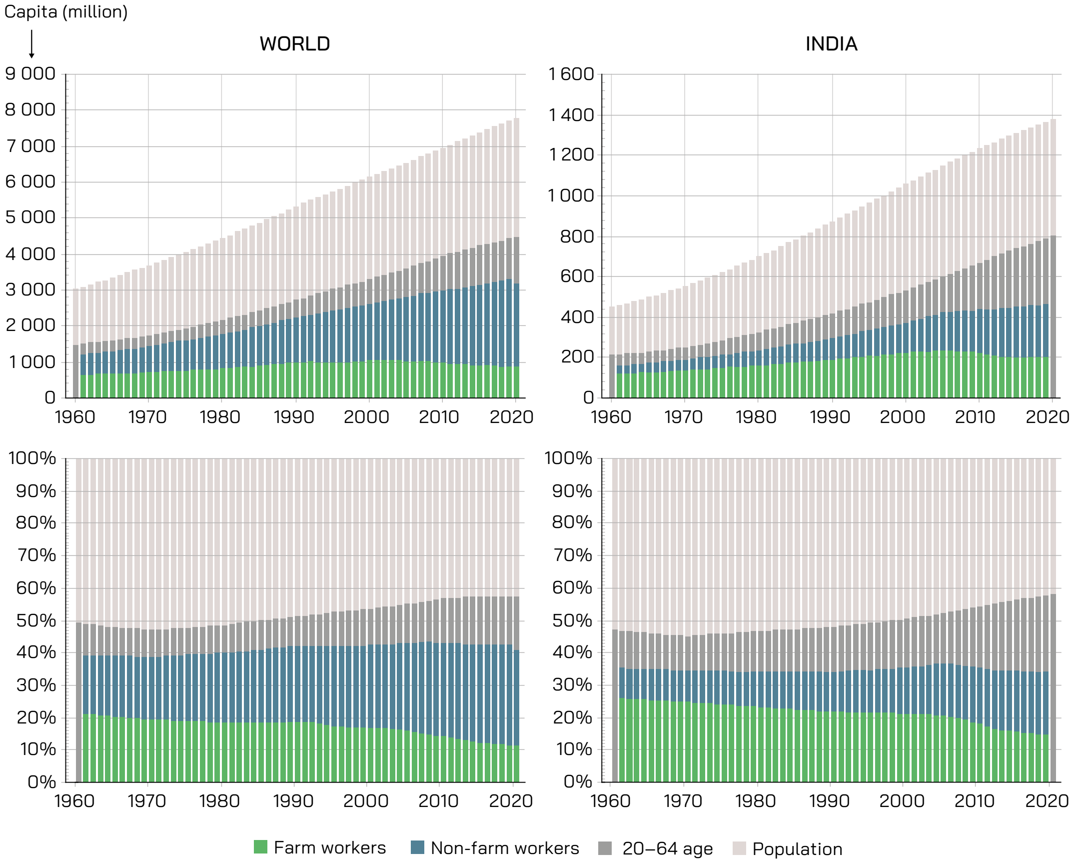


Figure 15

Population and employment – world and India, 1961–2020 (capita and share by category)

Source: Dorin, 2023.

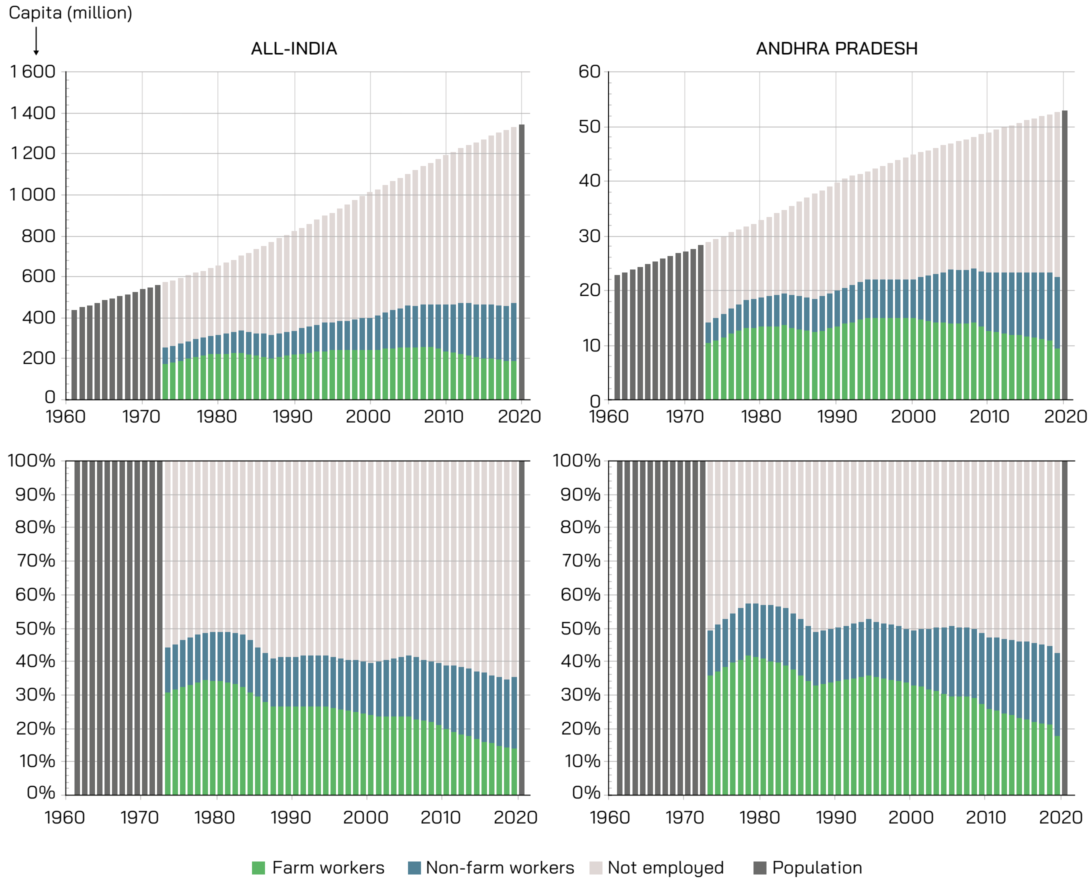


Figure 16

Population and employment – all-India and Andhra Pradesh, 1961–2019 (capita and share by category)

Source: Dorin, 2023.

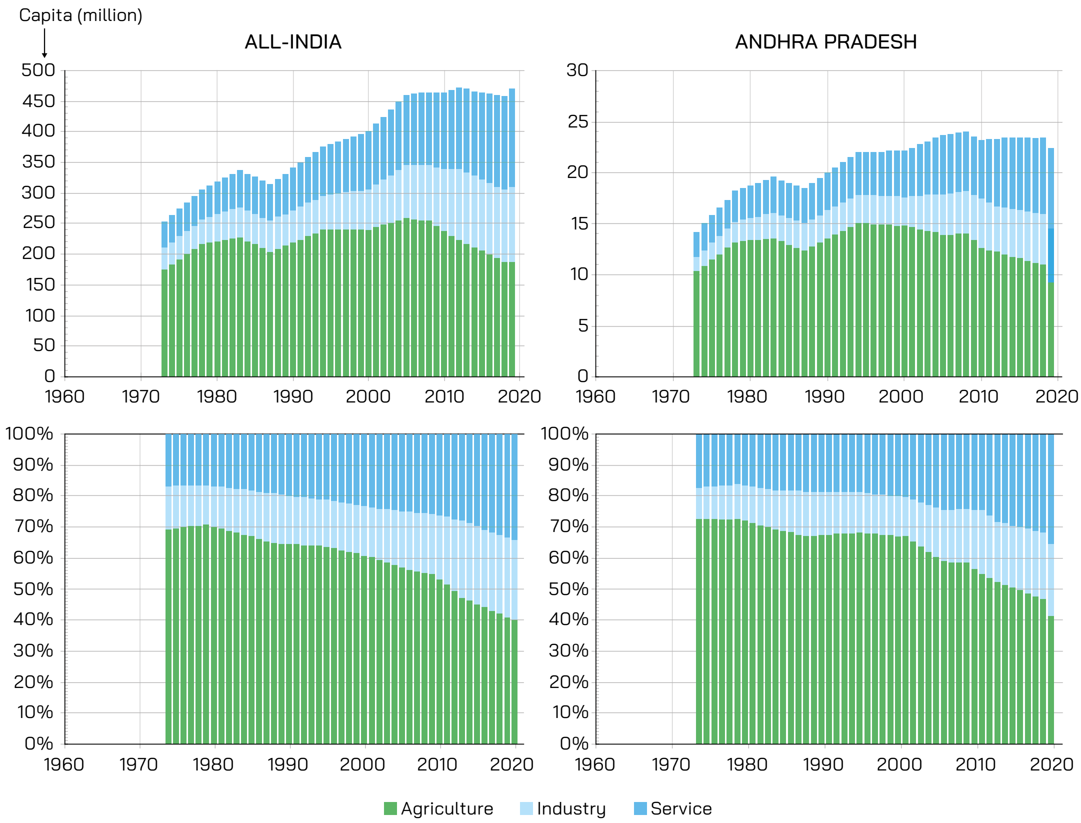


Figure 17

Employment by sector – India and Andhra Pradesh, 1973–2019 (capita and share per category)

Source: Dorin, 2023.

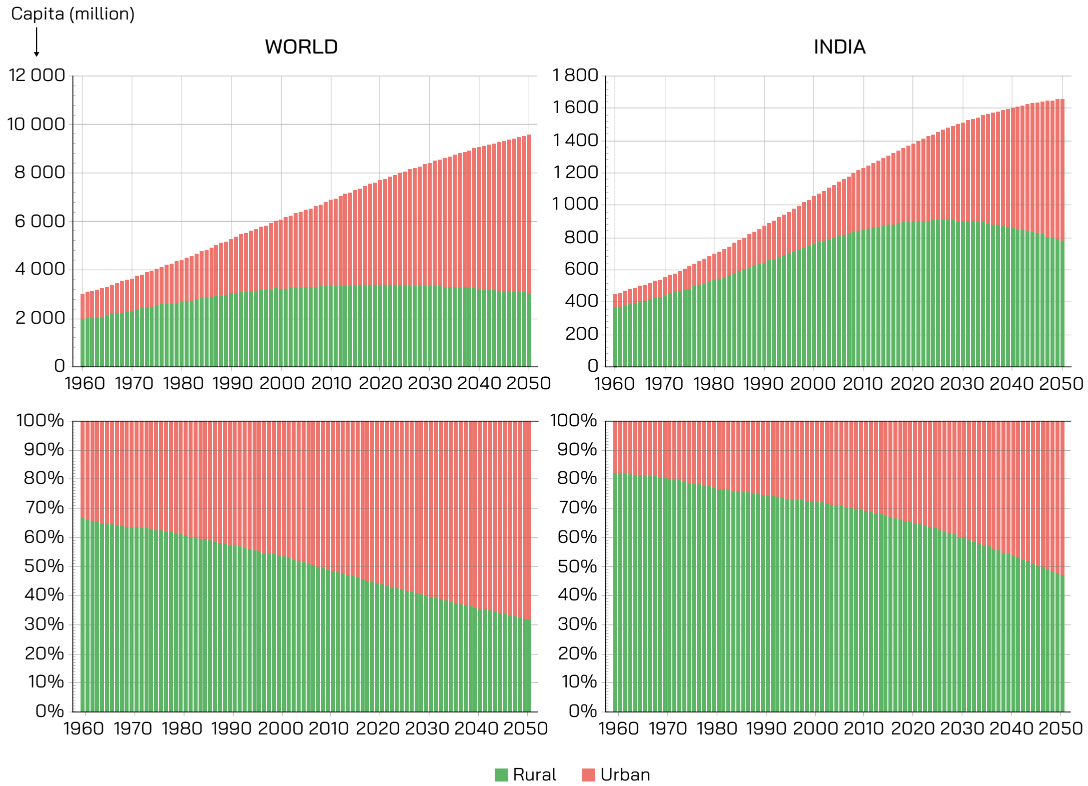


Figure 18

Rural and urban population estimates and forecast – world and India, 1961–2050 (capita and share by category)

Source: Dorin, 2023.

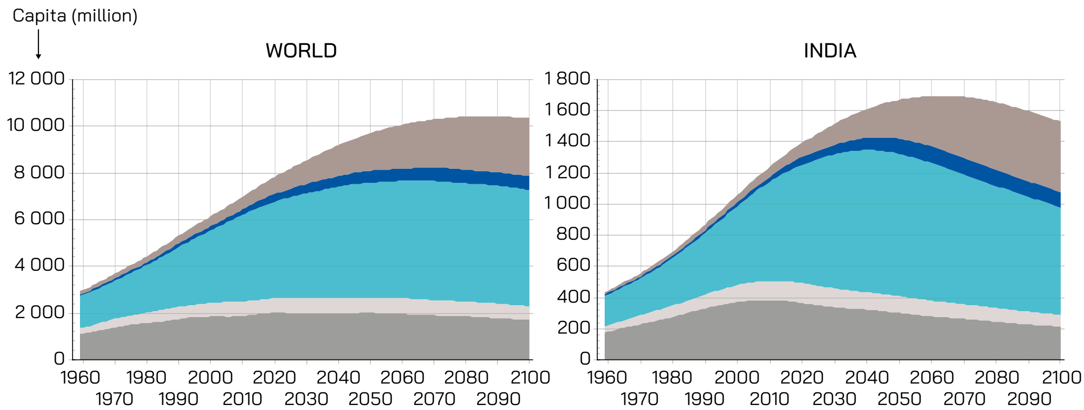


Figure 19

Population estimates and forecasts – world and India, 1960–2100 (capita by age group)

Source: Dorin, 2023.

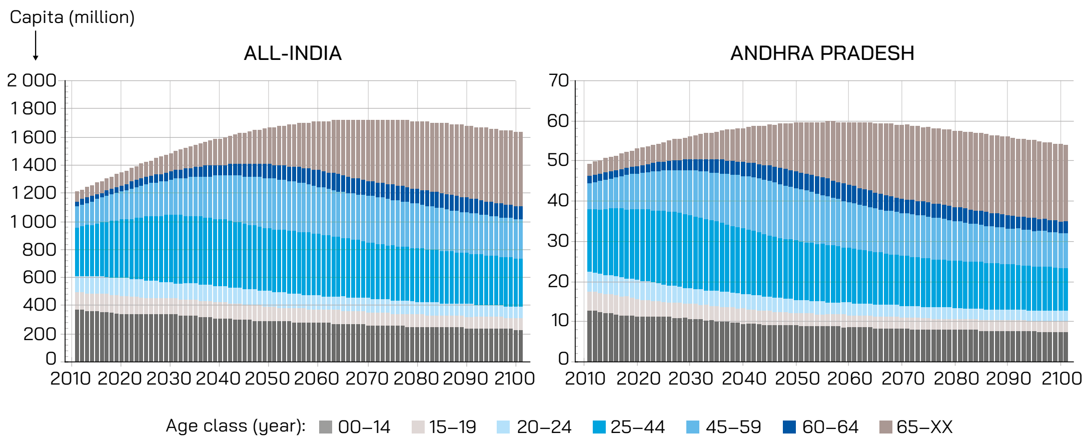


Figure 20

Population forecasts – all-India and Andhra Pradesh, 2011–2100 (capita by age group)

Source: Dorin, 2023.

3.3 ECONOMIC GROWTH AND INEQUALITY

The gross domestic product (Simon Kuznets, 1932) is an approximation of the overall value of both production and income of a Nation or a State. In technical terms, the GDP is the sum of gross values added (GVA) *plus* taxes *minus* subsidies, and the GVA of a branch of activities is the sum of all its sales minus the value of inputs (or "intermediary consumptions") used to produce them (in agriculture: seeds, fertilizers, pesticides, animal feed, repairs and maintenance charges, etc.). The GVA is therefore used to remunerate what are called the "primary factors" of production, i.e. labour and capital (including land, owned or leased). It is a fair proxy of the income of a branch of activity, and if we divide it by its number of employees, it also gives a fair proxy of the "labour productivity" or average income per worker. However, in order to study the evolution of these revenues over time and space, GVAs must be deflated to discount inflation (depreciation of the currency over time). In other words, the values of GVAs in current or "nominal" terms must be converted into constant or "real" prices, using a reference period (called the "based year" of a series) that changes from time-to-time (often every ten years).

The **World Bank** estimated that the **2019 world GDP per capita was 11 417 in current USD, i.e. about 31.3 USD or 2 221 INR per day**. Figure 21, generated by Agribiom-World with UNSTAT (2022) data on GVA (as well as with United Nations/ILO data on population and employment), display the evolution for 50 years (1970–2019) of World and India's average per capita GVA in constant USD of 2015 (USD–2015). There are striking differences at least on two points:

- **India's average GVA per capita was multiplied by 5** over half a century (by about 2 at the world level) but in **2019, it remains 6 times lower than the world average** (5.1 USD–2015 per day per capita against 28.7);
- **India' share of agriculture in GVA declined from 53 percent in 1970 to 16 percent in 2019**, but remained about **4 time higher than the world average** in 2019 (4.4 percent) which, of course, hides great disparities between countries, especially between OECD countries and the rest of the world (Dorin *et al.*, 2013).

Overall, in constant USD-2015, the world seems to be engaged in a "Farming Developing" path since 1970 after being, until the mid-2000 (until the increase in the total number of farmers stopped in 2003) almost in a Lewis Trap. **India**, on the other hand, is certainly **embarked on a "Lewis Trap" since 1970** (Figure 22) as with most other Asian countries (including China).

Figure 23 and following, generated by Agribion-India for All-India and Andhra Pradesh (see Annex 1.3 for data sources and management), display our estimates of GVA in constant rupees at 2011-12 prices (INR-2011). At the All-India level we observe a similar per capita increase (multiplication by 5.3 between 1970 and 2019) and a similar decrease in the share of agriculture (down to 14.8 percent in 2019). Table 3, which compares annual growth rates of different indicators across All-India and Andhra Pradesh, shows that **Andhra Pradesh** experienced **lower population growth and higher GVA per capita growth**, mainly due to **higher growth rates of total agricultural GVA**, especially since 2010 and the rise of fisheries. Overall, since 1980 (not 1973 as for all-India, due to state GVA limitations), **Andhra Pradesh followed a "Farmer Excluding" path over 1980-2019** (Figure 25, Figure 26).

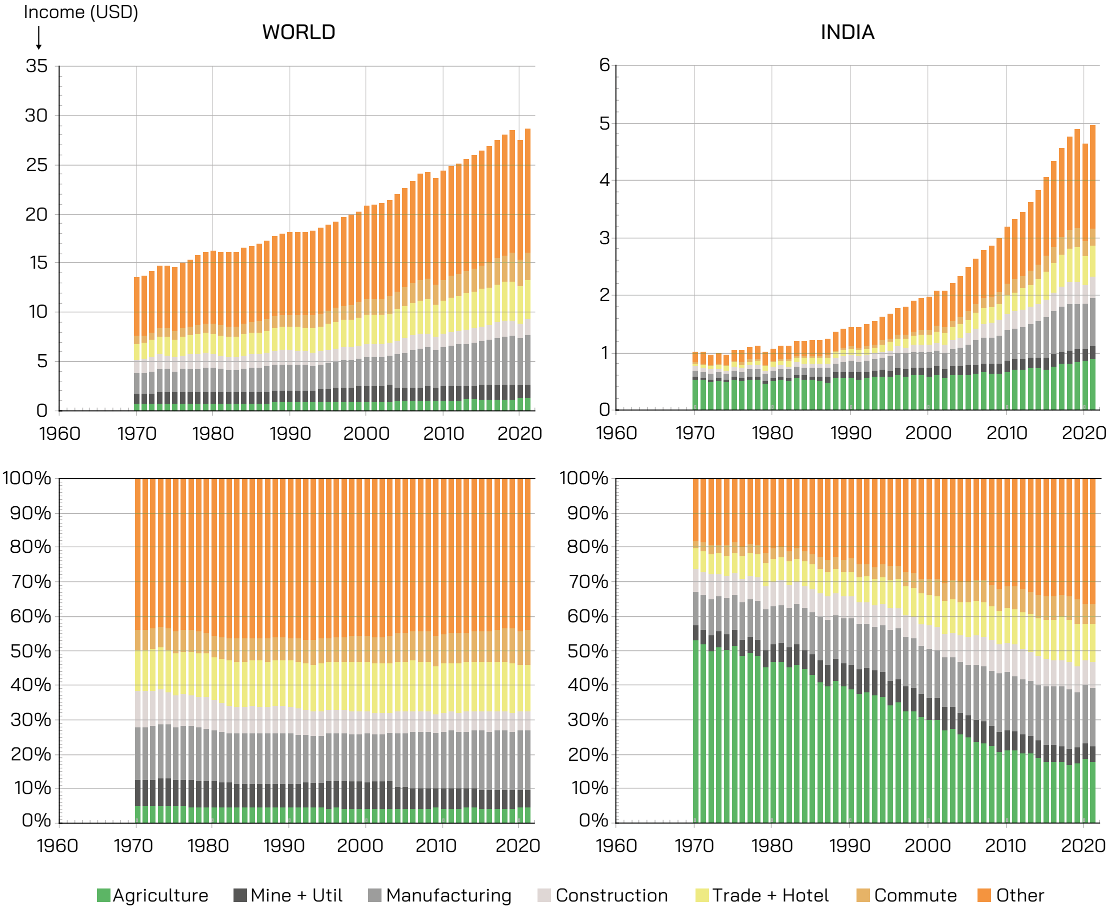


Figure 21

Average gross value added per capita per day – world and India, 1970–2021 (USD-2015 and sectoral shares)

Source: Dorin, 2023.

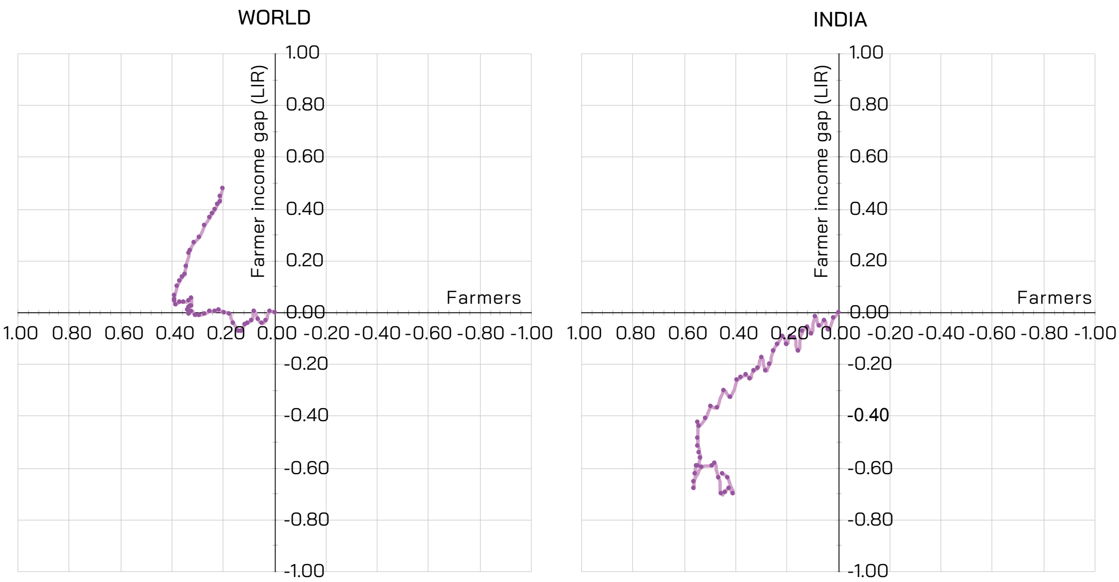


Figure 22

Structural path – world and India, 1970–2020

Source: Dorin, 2023.

Figure 23

Gross value added – all-India and Andhra Pradesh, 1960–2019 (INR-2011 and sectoral shares)

Source: Dorin, 2023.

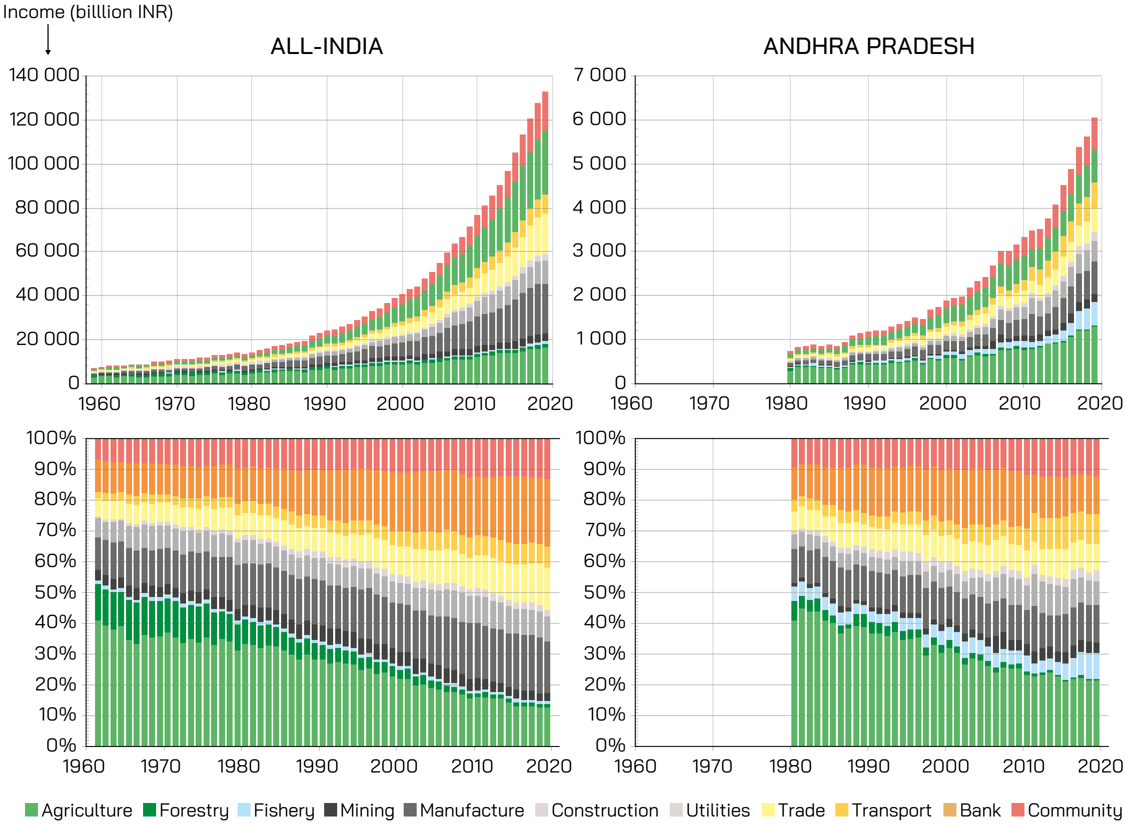


Figure 24

Annual grown rates for gross value added – all-India and Andhra Pradesh, 1960–2019

Source: Dorin, 2023.

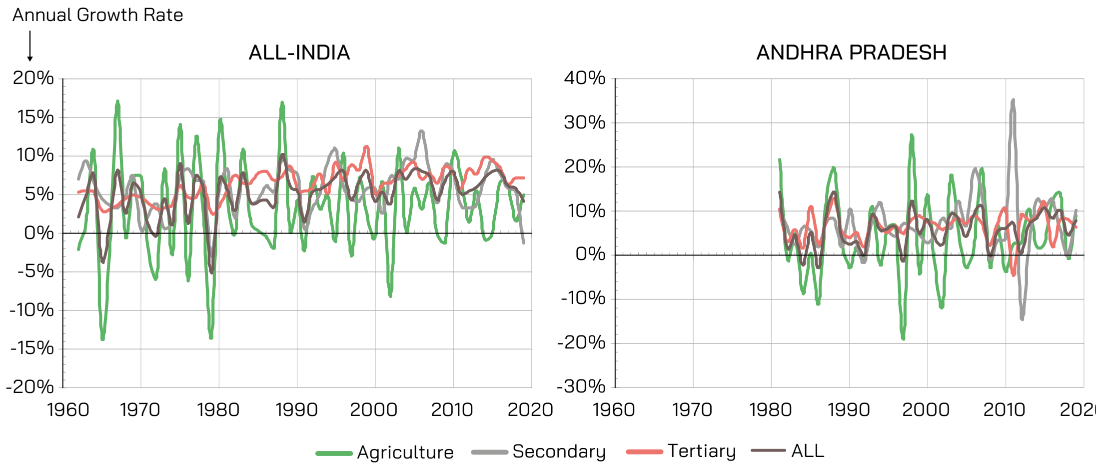
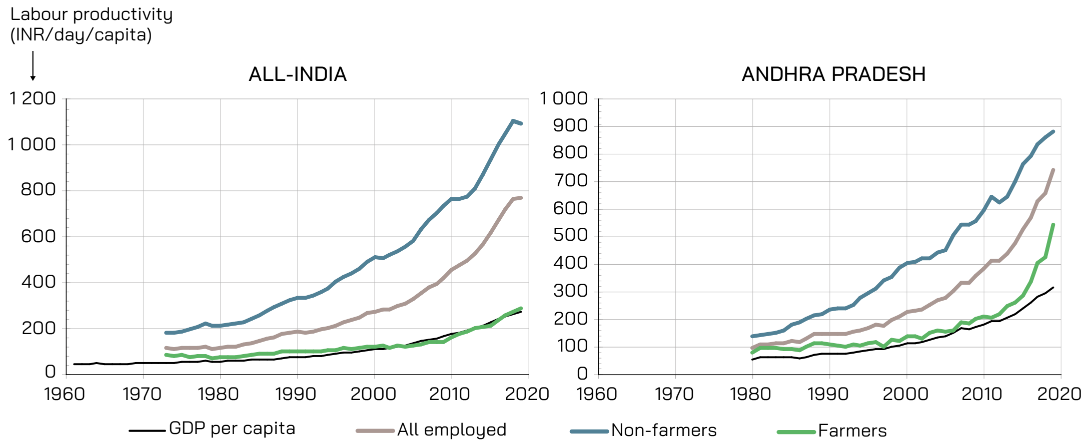


Figure 25

Farm and non-farm labour productivity – all-India and Andhra Pradesh, 1973–2019 (INR-2011 per capita per day)

Source: Dorin, 2023.



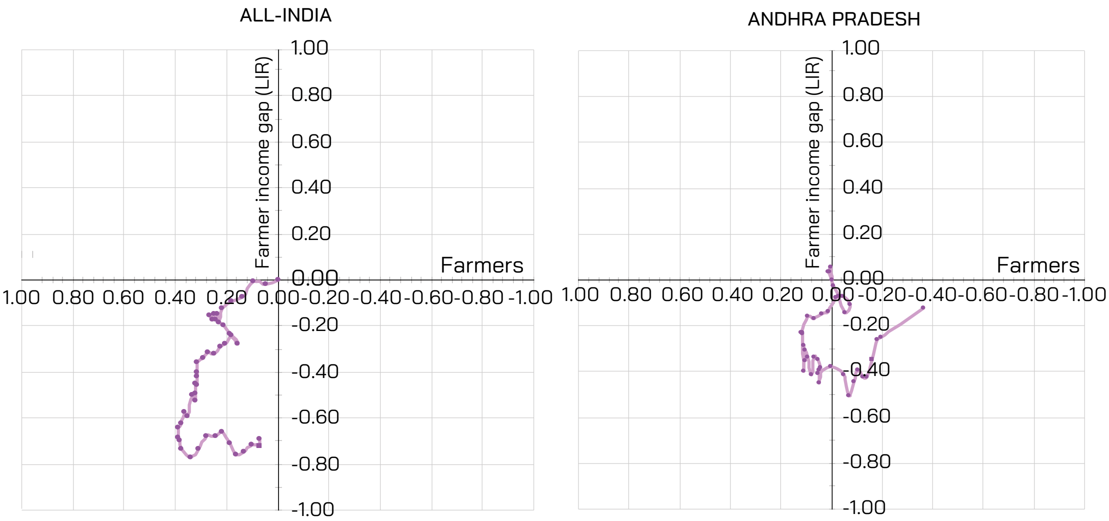


Figure 26

Structural path – all-India and Andhra Pradesh, 1973–2019

Source: Dorin, 2023.

Table 3. Population and gross value added annual grown rates – all-India and Andhra Pradesh, 1980–2019

From year x to 2019		Population %	GVA (all) %	Farm %	Non-farm %	GVA/capita %
India	1980–2019	1.84	6.00	3.05	7.18	4.08
	1990–2019	1.68	6.21	3.05	7.25	4.46
	2000–2019	1.47	6.48	3.28	7.31	4.94
	2010–2019	1.23	6.23	3.76	6.72	4.93
Andhra Pradesh	1980–2019	1.22	5.78	3.99	7.25	4.51
	1990–2019	0.97	6.11	4.38	7.25	5.08
	2000–2019	0.85	6.51	4.85	7.44	5.61
	2010–2019	0.79	7.12	7.25	7.06	6.28
By decade		**Population**	**GVA (all)**	**Farm**	**Non-farm**	**GVA/capita**
India	1980–1989	8.23	5.38	3.00	7.04	-2.63
	1990–1999	2.10	5.88	2.90	7.29	3.70
	2000–2009	1.69	6.56	2.21	7.84	4.79
	2010–2019	1.23	6.23	3.76	6.72	4.93
Andhra Pradesh	1980–1989	4.45	5.13	3.61	7.08	0.65
	1990–1999	1.21	5.05	2.48	7.13	3.80
	2000–2009	0.91	5.96	3.15	7.62	5.00
	2010–2019	0.79	7.12	7.25	7.06	6.28

Notes: GVA – gross value added; Source: Dorin, 2023

3.4 FOOD YIELD AND PRODUCTION

For nearly 10 000 years, human beings have domesticated nature and developed agriculture to satisfy their basic need: food. Every day, this food must provide them with energy (calories), macronutrients (carbohydrates, proteins, fats),[7] fibre and micronutrients (vitamins and minerals) in sufficient and balanced quantities to lead a healthy and active life. Concerning energy only, it is estimated today that, at the country level, the average available food per inhabitant should reach at least 3 000 kcal/day to secure everyone's energy needs rather well (varying according to climate, age, gender, activity, etc.) if household food waste, inequality between rich and poor and/or share of animal products in the diet are not abnormally high.

In the FAO accounting system (https://www.fao.org/faostat), the country food availability in kilocalories is estimated as follows: FOOD = PRODUCTION + IMPORT – EXPORT +/– STOCK VARIATION – SEED – ANIMAL FEED – WASTE – NONFOOD USE (biofuels or else). At the country level, these food availabilities (FOOD) are first estimated annually, in tonnes and product-by-product (whether of vegetal, animal or aquatic origin), then converted and aggregated into calories. The total of FOOD in calories therefore depends on the products included in the calculation (usually commodities for which statistics exist for each element of the above equation), as well as the nutritive factors used for each of them.

Thereafter, we only focus on agricultural plant production (PRODUCTION) edible in their primary form (e.g. tonnages of cotton fibres are not included unlike cotton seeds). But unlike FAO, we converted these productions into calories (as well as into carbohydrates, proteins and fat), then distributed them per inhabitant, per farmer or per cultivated hectare to obtain rough estimates of, successively, the capacity of a region to meet the dietary calorie needs of its population, the productivity of agricultural labour and the productivity of land in food calories. Under no circumstances should these production estimates be confused with food availability estimates, especially because food availability (FOOD) subtracts from food production (PRODUCTION) net trade, seed, waste and important possible uses of human-edible products such as animal feed or biofuels.

Figure 27, generated by Agribiom-World with the production tonnages of the Food Balance Sheets of the FAO (FAOSTAT, 2022) and the nutritive factors "for international use" (FAO, 2001), display the evolution over 60 years (1961–2020) of World and India's food production in food calories. Figure 28 divides these estimates per capita and per farmer, and Figure 29 by cultivated area. From these estimates we can note the following features:

- The world **production of plant foods in calories has multiplied by 3 in 50 years (1970-2019)**, as in India where the growth has even been slightly higher (2.3 percent per annum on average against 2.2 percent per annum).
- The **Indian production of plant food was about 1 531 Tkcal in 2019**, or **4 194 Gkcal/day**, which is almost **10 percent** (9.7 percent) **of the world production**.
- In India, due to the strong concomitant increase in the population, the plant food production per inhabitant evolved over twenty years around 2 670 kcal/capita/day (1988–2009) before reaching **3 000 kcal/capita/day from 2018**; a similar trend is observed at the world level (including India) but to reach a much higher level in 2019: 5 560 kcal/capita/day (Figure 28).
- Similarly, the plant food production per farmer stagnated below 15 000 kcal/farmer/day in India till the mid-2000s (i.e. one farmer could theoretically feed 5 people) before jumping to almost **22 000 kcal/farmer/day in 2019** (due to the drop in the number of farmers: see section 3.2) when it is 50 000 at the global level (Figure 28).

7 These macronutrients are also the source of energy, according to the following international conversion factors (used in this study) for 100 grams of macronutrients: 4 kcal for carbohydrates and proteins, 9 kcal for lipids (fat).

- The story is quite different with yields: over 50 years (1970–2019), **Indian food yields in calories have increased by nearly 3 percent per annum to reach around 25 000 kcal/ha/day in 2019**, when it was 2.5 percent per annum globally to reach 27 600 in 2019 (Figure 29).

Figure 30 and following, generated by Agribiom-India for All-India and Andhra Pradesh (see Annex 1.4 for data sources and management) display our estimates of plant food production. **With Agribiom-India, evolution is similar but estimates are slightly higher** for India (compared to Agribiom-World): **4 375 Gkcal/day of plant food production in 2019** (against 4 194 with Agribiom-World, i.e. less than 5 percent difference) due to more detailed crops and Indian nutritive factors (Longvah *et al.*, 2017). We then have about **3 290 kcal/capita/day**, **23 300 kcal/farmer/day** and **30 700 kcal/ha/day**, when **for Andhra Pradesh in 2019**, it was successively about **3 670 kcal/capita/day** (+12 percent), **20 700 kcal/farmer/day** (–11 percent) and **31 100 kcal/ha/day** (+1 percent).

However, while the Green Revolution primarily aimed to reduce world hunger by increasing the area and yield of few food crops, India's current Global Hunger Index is considered severe, having the highest child wasting rate in the world at 19.3 percent (Grebmer *et al.*, 2022). According to UNICEF (2019), 69 percent of deaths of children under 5 years old in India are due to malnutrition, and according to the latest National Family Health Survey (IIPS and ICF, 2022), 19 percent of women and 16 percent of men are still suffering from an index lower than normal body mass while 23-24 percent of 15–49 year olds are now overweight or obese. In fact, with the Green Revolution, India became self-sufficient and even a major world exporter of rice, wheat and sugar, but also a major world importer of pulses and vegetable oils, while fruits and vegetables are increasingly expensive on the domestic market. In other words, with the Green Revolution, India avoided the famines it experienced in the past while its population has tripled in 60 years (1960–2020), which is a major achievement, but is yet far from being nutritionally secured.

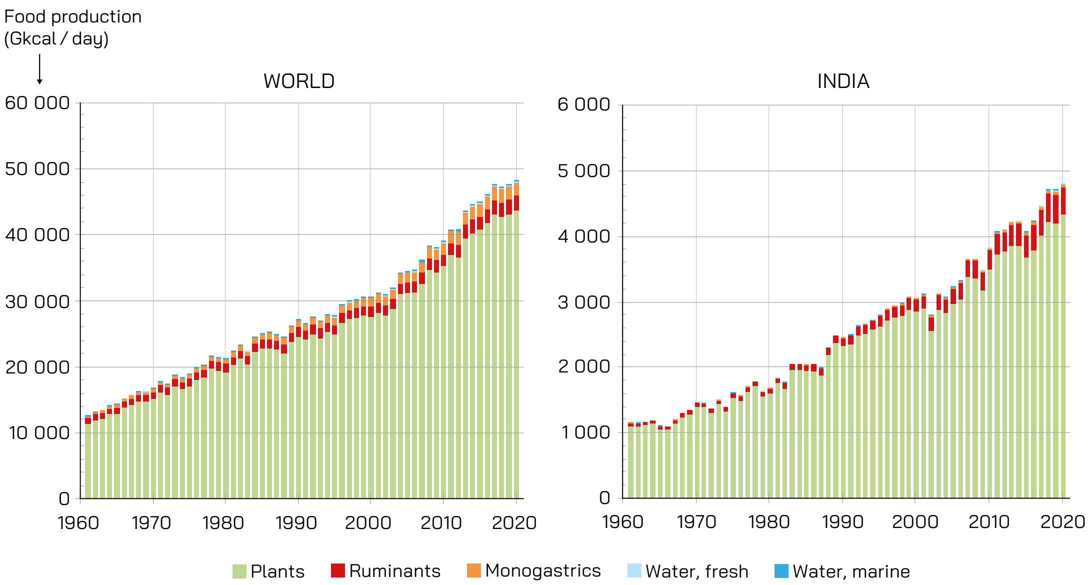


Figure 27

Food production in calories – world and India, 1961–2020 (Gkcal/day)

Source: Dorin, 2023.

Figure 28

Plant food production in calories per capita and per farmer – world and India, 1961–2020 (kcal/day)

Source: Dorin, 2023.

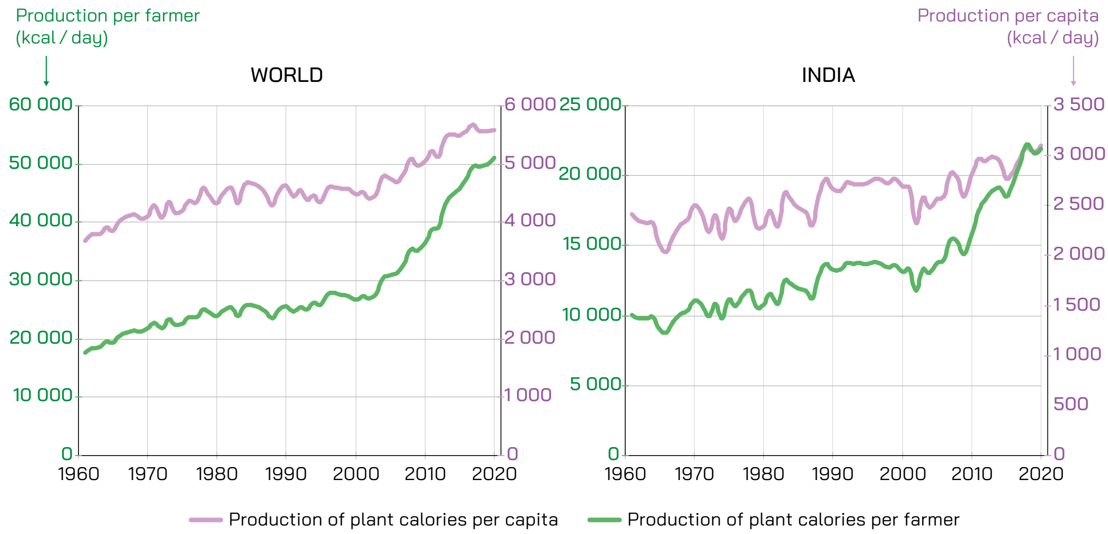


Figure 29

Yield in plant food calories per cultivated hectare – world and India, 1961–2020 (kcal/day/ha)

Source: Dorin, 2023.

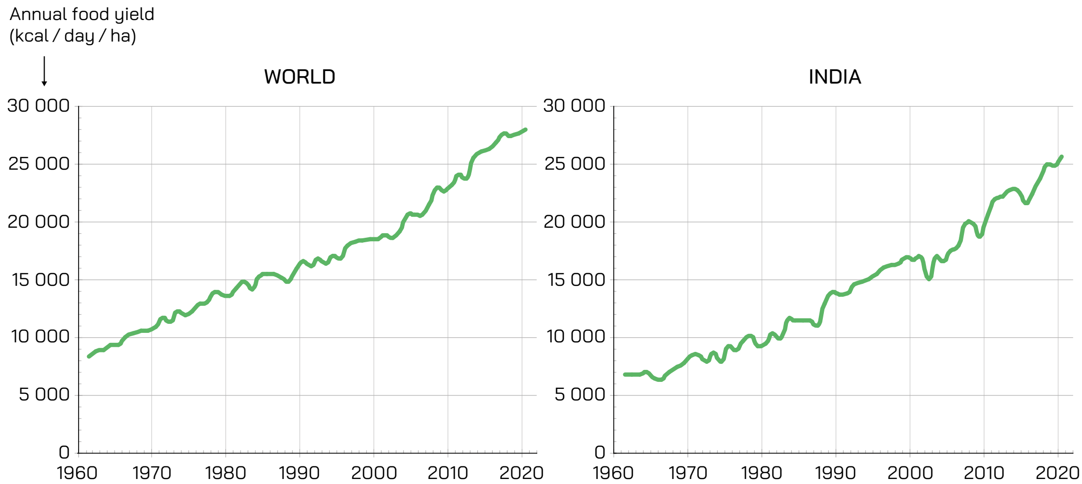
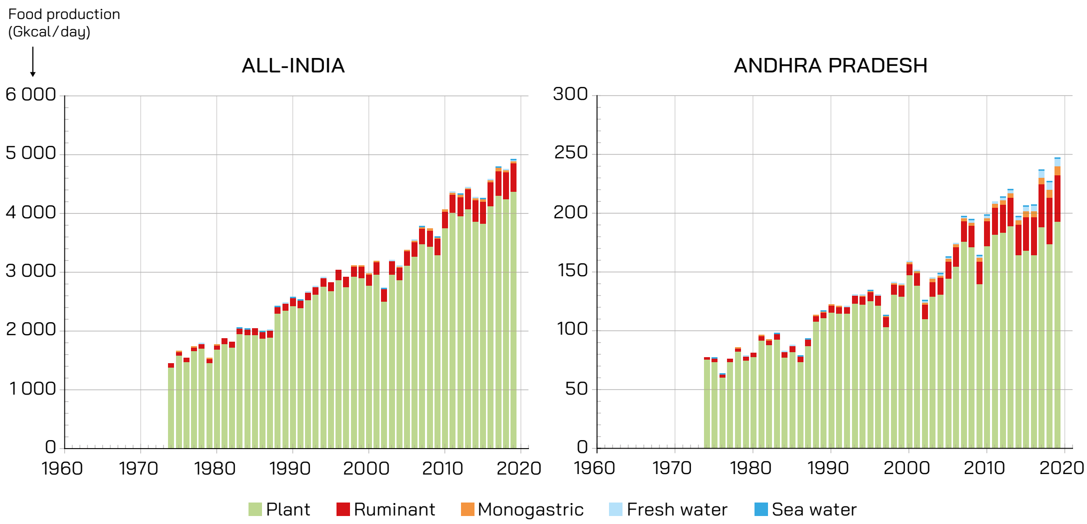


Figure 30

Food production in calories – all-India and Andhra Pradesh, 1974–2019 (Gkcal/day)

Source: Dorin, 2023.



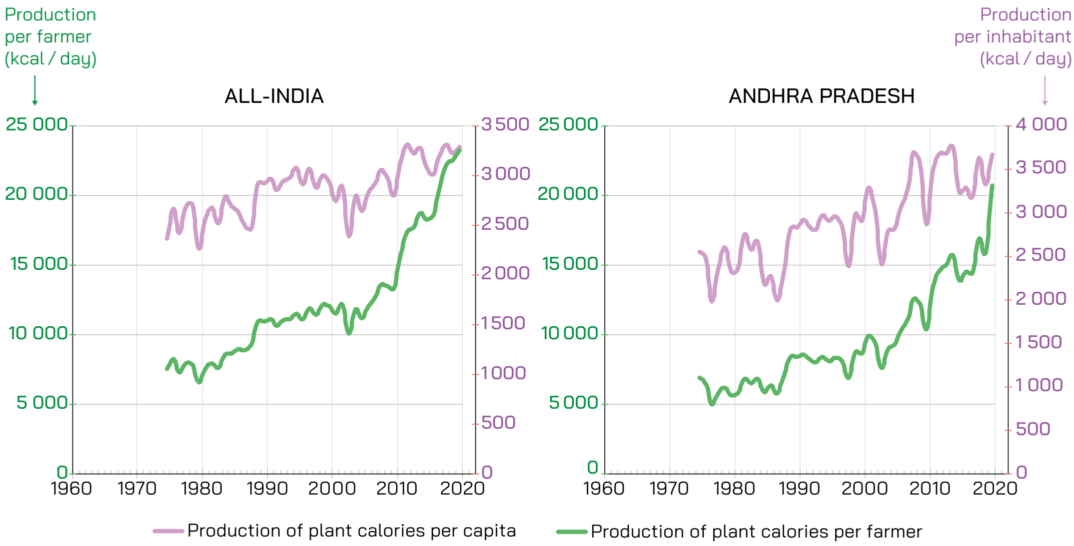


Figure 31

Plant food production in calories per capita and per farmer – all-India and Andhra Pradesh, 1974–2019 (kcal/day)

Source: Dorin, 2023.

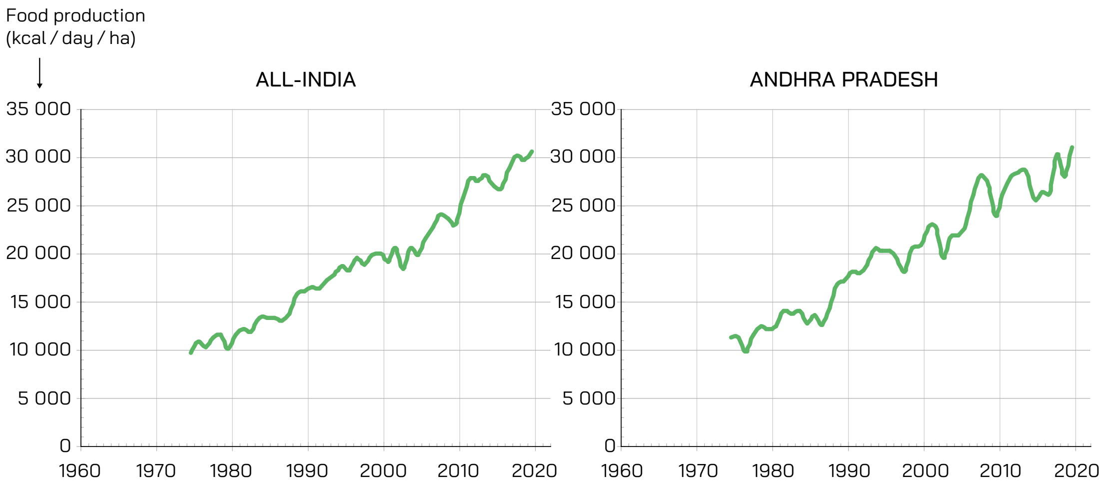


Figure 32

Yield in plant food calories per cultivated hectare – all-India and Andhra Pradesh, 1974–2019 (kcal/day/ha)

Source: Dorin, 2023.

3.5 MAIN LESSONS AND CHALLENGES

By examining historical patterns, the analysis of structural transformations enables us to harness insights from past trends to envisage emerging interconnected challenges from land use, population dynamics, economic growth and food production. Acknowledging these constraints and trends is a necessary condition to shape scenarios for agrifood systems for Andhra Pradesh that are resilient, environmentally sustainable and capable of meeting future food demands.

In terms of land use, there are two direct constraints to be addressed: on the one hand, the limited availability of cultivable land; on the other hand, the increased levels of land erosion and degradation due to unsustainable practices and climate change. The interplay between these two factors is likely to negatively affect agricultural productivity and food security. Therefore, the optimization of land use requires adequate consideration. This implies maximizing farm productivity through practices that increase crop intensity (crop diversification, multiple cropping systems, crop rotations and optimized planting schedules) and sustainable land management (in particular to restore, protect and enhance soil fertility and health). Such strategies would also enable the increase of land productivity per farmer to maximize agricultural output. Water scarcity and climate change are putting an acute additional burden on land use and availability, which also emphasises the need for efficient and sustainable water management (efficient irrigation, water and moisture conservation and retention practices, alternative water sources) to mitigate the negative impacts.

In terms of population and employment, current trends in Andhra Pradesh (and India) show a population increase that is projected to continue over the coming decades, highlighting the need to ensure access to sufficient, safe and nutritious food for all. Special consideration should be given to the sharp increase in the young population. At the same time, employment shows a stagnation of the employed since the mid-2000s. In addition, the number of farmers in the State has been declining in recent years, possibly as a result of the limited land availability and low profitability; lack of attractiveness of farming; mechanization; and changes in agricultural practices. These trends present both a challenge and an opportunity, and reinforce the need to enhance farm productivity (as posed by the land use constraints) and to create opportunities for youth employment and income generation for a growing population. Urbanization in Andhra Pradesh is progressing at a slower pace than global trends, therefore, rural areas and agriculture could continue to play a crucial role in the State's development.

In terms of economic growth and inequality, the increase in per capita GVA in the State indicates positive economic growth, despite the lower population growth. In fact, Andhra Pradesh has been under the "Lewis Trap" since 1970, not absorbing surplus agricultural labour into the non-farm sector, leading to underemployment or unemployment and a growing farm–non-farm income gap. This suggests that economic growth has not been inclusive. Such trends call for a more comprehensive approach to agricultural development, bridging economic disparities, fostering inclusive growth and social equity.

In terms of food production and yields, over the years there has been a significant increase in food production globally, as well as in India, including in Andhra Pradesh. However, the strong concomitant increase in population has, and will continue to, put pressure on food availability. While the per capita plant food production in India increased, there is still a need to keep pace with the appropriate energy requirements of a growing population, in particular to achieve a balanced diet that includes macronutrients, fibre and micronutrients. In addition, while we observe an increase in plant food production per farmer, this increase may be attributed to a drop in the number of farmers. In conclusion, there have been positive trends in food production and yields in Andhra Pradesh, especially in the form of the increasing share of more nutritious food with faster growth in horticulture among plant-based foods, and in livestock and fish-based products. Sustaining these gains and addressing associated challenges of balancing land and labour productivity, environmental sustainability, and nutritional requirements will be crucial.

Such systemic challenges are in line with recent global reports which stress the need to adopt proven strategies for enhancing nutrition, ecosystem health, sustainable and resilient agrifood systems (FAO, 2021).

4. Scenario of Natural Farming (NF) in 2050

4.1 GENERAL PRINCIPLES

The following general principles of the NF scenario emerged from the extensive discussions during the seven virtual expert workshops (September 2020 to June 2021) and the two in-person workshops in Anantapur (September 2021) and Delhi (November 2022):

> ***An SDGs-oriented society based on higher income equality, moderate urbanization, diversified and chemical-free food production in Andhra Pradesh serving first local markets and local needs including environmental services, hybridizing scientific and indigenous knowledge, with community-managed natural farming (or agroecology) employing a large number of happy people in agriculture and related small-scale industries.***

The following sections present how these general principles were translated into qualitative and quantitative assumptions by the Expert Group of the Anantapur workshop, within a process that also checked the overall consistency of these assumptions across different domains, from land use to economic inequality.

4.2 LAND USE

4.2.1 Experts' main considerations

In the NF/AE scenario, large-scale transition of farmers to Natural Farming is expected to have significant implications for land use. In particular, salient points include that:

- **Current areas classified under forest and shrubs would be preserved**, given that soil health and productivity in cultivated lands would avoid encroachment on these areas.
- **Large areas under current fallow and even barren land would be converted into available productive land**, due to the restoration and regeneration capacity of natural farming/agroecology.
- **Cropping intensity on current and new agricultural lands would increase** to two or three major crop seasons in even rainfed areas.

Cultivated land would then total more than 8 million ha in 2050 (against 6 million today), as envisioned by the government of Andhra Pradesh from the year 2027 (RySS, 2019). Therefore, this increase in cultivable land would not be to the detriment of forests and shrubs, but it would come from the restoration of fallow and barren land and the recovery of their productive capacity. This is a major positive factor that is made possible by the regenerative capacities of NF on soils and ecosystems. However, the current trend in land markets towards purchase of all kinds of land including agricultural land for speculative purposes would need to be curtailed through land use regulation policy of the state.

The overall expansion of this agricultural land would be mitigated by the development of urbanized areas (cities, villages, factories, roads, etc.). In this scenario, urbanization is assumed to be at the same rate as in the past, i.e. about half of the rate of increase of the population, but driven by more of a network of small towns such as "census town" and not by large agglomerations (Reddy, 2017).

Experts thoroughly discussed the sustainability implications of future agrifood systems in Andhra Pradesh, especially on the land use and related derived dimensions, both physical (such as soil fertility, water scarcity or climate change impacts) and institutional (such as size distribution of holdings or the tenancy system).

On the institutional dimensions, except in the case of land classified as "forests", there is no regulation on land use in Andhra Pradesh, and over the last decade there has been rampant expansion of land market and purchase of cultivated, waste and even barren land for speculative purposes, diverting the use away from agriculture. The assumption that NF/AE would improve the soil quality and succeed in bringing about an additional two million hectares under plough by 2050 has then to be backed by the conditional assumption of effective state land use policy and regulation. The second institutional aspect of land use refers to the size-class distribution of land holdings, and the question of ownership and tenancy, which have implications for the livelihood of cultivators.[8] In Andhra Pradesh, as in the rest of India, the size distribution of operational landholdings is extremely skewed. In India in 2018–19, with about 102 million operational holdings, the average was 0.913 ha, with small and marginal holdings (those with 2 ha or less) accounting for about 89 percent of all holdings and 56 percent of the total area cultivated (NSO, 2021).

Regarding tenancy, according to the same official survey, about 17 percent of operational holdings have reported partial or entire holding as leased-in, and account for about 13 percent of the area cultivated in 2018–19 in India. However, the incidence of tenancy and rental values vary across the Indian states and their regions. In Andhra Pradesh, informal discussions suggest that the highest incidence of tenancy, over 60 percent of the holdings, is in the Godavari region, with rental values per hectare ranging INR 50 000 to almost 100 000 for certain types of land. In the rainfed region of Anantapur, the incidence of tenancy is lower, less than 20 percent, with rental values ranging from 5 000 (especially fallows and barren) to INR 12 000 per hectare, while in tribal regions, the incidence of tenancy is almost negligible.

The purpose of taking on board these two elements of current reality (size distribution of land holdings and incidence of tenancy) is to show different implications for the 2050 scenarios. In the case of NF/AE with many farmers (see Section 4.3), the ideal-type is that of the small farm, which should also be an ideal-type with low tenancy rate since tenancy is mainly carried out on large holdings (ideally non-existent in this scenario) to small-marginal holdings. This should then increase the economic viability of these small farms (Section 4.4) and their overall inclusion in the economy (Section 6.4). On the contrary, in the case of IA with fewer farmers (Section 5.3), small-marginal farmers are likely to wither away and tenancy may take the form of what is called "reverse tenancy", i.e. larger farmers leasing-in to increase the size of holdings to allow for more mechanized farming.

What would be the productivity of these small farms in the NF/AE scenario? Issues related to food production and yields were also discussed and are presented in more detail in a following section (Section 4.5). Overall, from the standpoint of production, agroecology is a paradigm that is more knowledge-intensive than input-intensive. Expert Group participants felt that certainly, technological development in industrial agriculture would also lead to reduced use of chemical inputs. However, in the words of one participant (echoed by many), "incremental improvements in the efficiency of conventional agriculture will not address the climate crisis, biodiversity loss and malnutrition – after all, such attempts have been tried for decades, but have failed yet to address the massive degradation and yield stagnation we see today".

In this NF/AE scenario Expert Group members indicated that the **conversion and expansion of agricultural land into community-managed agroecology** would help increase:

- agricultural employment and income from agriculture due to more labour and knowledge-intensive techniques than in industrial agriculture;
- food and feed production thanks to the restoration of soil health and ecosystems functions, higher

8 In India, the term "cultivators" is used for those who own or rent land, alongside "agricultural labourers" of whom cultivators may also be temporarily part (Aubron *et al.*, 2022).

cropping density in polycultures and higher cropping/tree intensity through the year, regreening of fallow lands;

- agrobiodiversity and resilience to biotic or abiotic shocks (typhoons, floods, droughts, rise in fertilizer and oil prices, etc.) (Valencia *et al.*, 2022);
- soil organic carbon (SOC) sequestration which boosts land productivity as well as mitigate climate change (Rumpel *et al.*, 2020; Soussana *et al.*, 2019; Lal, 2020);
- restoration of landscape and healthy water cycles which also contribute to cooling the climate.

With regards to soil health restoration, ecosystem health, increased agrobiodiversity and resilience, experts pointed to the increasing body of evidence concerning the potential of agroecological (including agroforestry) approaches to **restore degraded soils** and **strengthen adaptation and resilience to climate change** (Leippert *et al.*, 2020; Terasaki Hart *et al.*, 2023) through multiple ecosystem services (carbon sequestration, soil structure formation, nutrient and water cycling and greenhouse gas mitigation) (Sinclair *et al.*, 2019) that even conventional organic farming would not provide (Gaudaré *et al.*, 2023).

In the "commodity-centric" vision of the Green Revolution, soil is seen as a place to deploy seeds that maximize output per unit area given the right doses of water, fertilizers and pesticides, whereas in agroecology, the soil is seen as "a complex, interacting, living eco-system to be cherished and maintained so that it can become a vibrant, circulatory network, which nourishes the plants and animals that feed it" (Shah, 2021). This implies a shift from flow-through nutrient management with chemical fertilizer application to a nutrient recycling model, with increased optimization of natural processes such as biological nitrogen fixation and mycorrhizal relationships (Prates Júnior *et al.*, 2019).

In addition, the assumption about the restoration capacity of degraded lands through natural farming relies on positive developments that APCNF has begun to illustrate in semi-arid areas such as in the Anantapur district, one of the driest districts of India. Since 2019, one of the techniques adopted here by farmers is pre-monsoon dry sowing (PMDS) which has resulted in 365 days of green cropped cover even in rainfed conditions.

Furthermore, based on current field results of the APCNF programme, through the implementation of premonsoon dry sowing, crop diversification and rotation, intensive poly-cropping, multilayer agroforestry models, year-round cropping successions with a "365 day Green Cover" approach, water-saving crops and techniques (such as mulch, green cover crops, rain and water vapour harvesting, drip irrigation, etc.), experts concurred that **cropping intensity on current and new agricultural lands would be increased** to two or three major crop seasons in rainfed areas, including for the production of fodder for livestock. As a result, farmers would optimize land use and yield a variety of products throughout the year. Healthy soils, with improved organic matter and nutrient cycling, would foster better crop resilience and increase annual yields.

Experts felt that the use of **commons** in this NF/AE scenario would remain an important aspect, including for grazing. Collective or group farming including on leased-in land would be legally permitted and facilitated. Animal husbandry would be carried out as part of integrated and small-scale natural farming.

Expert Group participants also emphasized the importance of the aesthetic and recreational value of the mosaic-like, **diversified landscapes** that would characterize the NF/AE scenario (as opposed to larger scale, more homogenous, monotonous and mechanized monoculture landscapes in the IA scenario). This scenario foresees, through the creation of enabling conditions, **human beings closely connected to the natural environment**, and an increased number of farmers as protagonists and stewards of natural resources governance, with positive impacts on ecosystem and human health.

Overall, this scenario would further boost food and feed production, preventing soil erosion, reversing desertification, and cooling the planet thanks to a 365-day plant cover during the year (Jehne, 2019).

4.2.2 Assumptions in numbers

Table 4. Quantitative assumptions on land use for the 2050 natural farming scenario

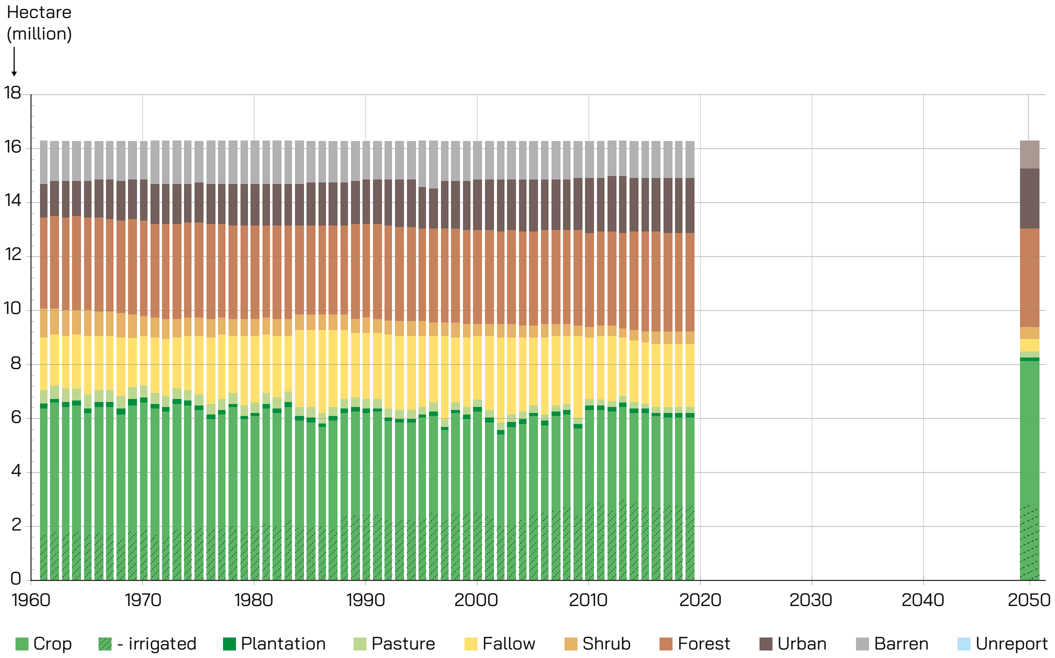
	Assumptions for the NF/AE scenario in 2050	2019 (Kha)	2050 (Kha)	AGR (%)
Total		16 297	16 297	
Cultivated (annual crops and plantations)	Hectares of 2019 all converted into NF + Fallow lands converted into NF + Barren land converted into NF – expansion of Urbanized areas	6 203	8 280	+ 0.94
- irrigated	45% of net cultivated land (as in 2019)	2 763 (45%)	3 726 (45%)	+ 0.97
Pasture	Hectares in 2019	209	209	
Fallow	Hectares in 2019 – 80%	2 383	476	– 5.06
Shrub	Hectares in 2019	414	414	
Forest	Hectares in 2019	3 688	3 688	
Barren	Hectares in 2019 – 25%	1 345	1 009	– 0.92
Urban	Hectares in 2019 + 8%	2 055	2 220	+ 0.25

Note: 2019 figures are 2017 figures due to unavailable official land-use statistics beyond 2017 in India (October 2021); Kha – thousand hectares; NF – natural farming; AE – agroecology; AGR – annual growth rate. Source: Dorin, 2023.

Figure 33

Land use in Andhra Pradesh 1961–2050 with the natural farming scenario

Source: Dorin, 2023.



4.3 POPULATION AND EMPLOYMENT

4.3.1 Main considerations from experts

In this NF/AE scenario for AP, as in the IA scenario, the Andhra population would increase as modelled by KC *et al.* (2018), with almost **60 million inhabitants in 2050**, including 51 percent in urban areas (against 39 percent in 2019, thirty years earlier). Similarly, the population aged 20 to 64, considered here as the population needing a job, would reach more than 35 million persons in 2050 (against 32.5 million in 2019).

Experts stressed the potential of employment generation through natural farming approaches. In this NF scenario, work is envisioned as a transformative activity of self, nature, and society, therefore it was considered a key feature of this scenario that at least **93** percent **of people aged 20 to 64 be employed in 2050** (i.e. 33 million people) against 69 percent only in 2019 (22.4 million people), which is largely due to low female participation in work. This would change under the NF scenario, which would bring more women into agricultural employment.

Urbanization in Andhra Pradesh has progressed at a slower pace than global trends in the past decade, and experts felt that in the NF/AE scenario, future urbanization would be of a different kind, driven by a network of small towns bringing markets, supply chains small-scale processing and non-farm employment in proximity to farming communities (Reddy, 2017). Rural areas and agriculture would continue to play a crucial role in the State's development. In this scenario, a large share of the employed would still work in agriculture and allied activities, far from the current model and figures of OECD countries (3 percent or less of employment). **The agriculture sector would represent 30** percent **of the employed population**, a decrease in percentage compared to 2019 (42 percent) but an increase in absolute number, to reach a total of **10 million people in 2050** (as in 1973) against 9.3 million in 2019.

In this scenario, **diversification of employment and income within agriculture and allied activities** is expected for farmers and rural communities. For example, **Community Resource Persons** (CRPs) are farmers who are currently practicing NF and who are hired as training and coaching experts in the APCNF programme; with the expansion of NF, they would significantly increase in number and would extend the peer-to-peer training of villagers. Similarly, throughout the state, the **natural input shops** (also called non-chemical input shops) that are set up by practicing farmers with support from the APCNF programme, would increase in number and create local employment and additional income opportunities for NF farmers making and selling agroecological inputs (biostimulants and other natural farming preparations, botanical pesticides, biocontrol agents, pest monitoring devices, local seed varieties, small implements, etc.).

In tribal villages, cooperatives set up through the Mutually Aided Cooperative Societies Act (MACS: Stuart, 2007) would continue working on **value chains for agroecological products** leading to employment and benefits for all involved. Similarly, in other parts of AP, farmer employment and labour productivity would increase as farmers would capture additional added value by storing, processing or selling on their farm or through their collective organization. Experts noted that markets for organic products have developed rapidly in India in past decades, and there was a further spur since March 2020 with the COVID-19 emergency, reflecting a shift in consumer preferences. The regional market for organic farming might double in size within a decade reaching INR 1 400 crore and the national market is expected to develop at a higher rate (between 30–35 percent) than exports, which are now valued at INR 2 500 crore (International Competence Centre for Organic Agriculture [www.iccoa.org], 2022). With these demand changes, the premium price for the natural farm products may also arrive at the farm gate. For natural farmers in AP, value chain development may take the form of product certification through new labels, or using the national organic scheme set up by the National Centre for Organic Farming (NCOF).

There is also the expectation that there will be novel work opportunities that would supplement farm employment. Additional employment and income opportunities would be generated through community-based **agri-ecotourism** (farm stays, guided educational tours, and interactive training workshops), a trend evidenced on organic and ecological farms around the world which has proven to sustain their income and reinforce their transitions to sustainable agriculture in different contexts (Khanal *et al*., 2019; Shen *et al*., 2020; Rana and Bisht, 2023). The influx of tourists would in turn boost demand for locally sourced products, further strengthening the market for natural produce. Beyond farmers, skilled individuals in hospitality, tourism management, and culinary arts would find employment in the agri-tourism sector as a result of the demand for guided tours, on-farm activities, and farm-to-table experiences. This would diversify income streams for farmers, promote rural economic development, help preserve local culture and traditions and contribute to social cohesion and local identity.

Experts debated **labour intensity** of natural farming and pointed to the limited research available, as agroecological or natural farming practices can vary significantly (Laske and Michel, 2022). Intercropping and mulching have the potential to reduce the need for labour intensive activities such as weeding. Creating organic inputs may demand more time than purchasing synthetic fertilizers or pesticides. Sowing, caring and harvesting complex multiple-crop systems is also more labour intensive than a monoculture that is sown, then harvested all at once with large seeders and combine harvesters.

However, farm-level synergies, especially those derived from increased levels of agrobiodiversity, can have a positive impact on employment and job creation (Garibaldi and Pérez-Méndez, 2019). Farmers engaged in agroecological transitions have the capacity to maintain more family members employed in their own agricultural production because they have higher returns from agricultural activities because of lower expenditures for external inputs and more sustainable marketing strategies (Fonseca-Carreño *et al*., 2019; Balla and Goswami, 2022; Lucantoni *et al*., 2023; Magaju *et al*., 2023). If the opportunity cost of more days in farming are compensated by fair pricing of their produce, then seeking employment through migration from other sources will decrease. In Andhra Pradesh, farmers practicing natural farming generally report that they find the investment of time in natural farming practices worthwhile as they prioritize harvesting healthy food while investing their savings in other farm-related activities, as opportunities for off-farm employment are limited.

In this line, and recognizing the emphasis of NF on labour and knowledge-intensive practices, experts envisioned a sustained demand for skilled work in various aspects of farming, such as agroecological management, organic pest control, composting and seed saving. Such skill intensity is *sui generis* (of its own kind) to the natural farmers. At the same time, it was agreed that the issue of labour intensity should be addressed through comprehensive indicators to properly capture its complexity.

When experts discussed how many farmers could be engaged in Natural Farming by 2050, they recalled that one of the main goals of APCNF was to promote sustainable farming as an attractive employment opportunity for smallholder farmers at scale, with the well-being of farmers and their livelihoods as a key target. In line with this vision, experts assumed that 10 million farmers would be practicing Natural Farming in 2050, i.e. 4 million more than envisioned by the Government of Andhra Pradesh for 2027 or even 2024 (6 million farmers: RySS, 2019). Such a large number would be a way for agroecological farmers and communities to **regain control over their work, knowledge and food**, and to design sustainable ways of farming (and eating) **in harmony with nature and local culture** (Rosset and Martínez-Torres, 2012; Poyyamoli, 2017; Altieri and Nicholls, 2020; Anderson *et al*., 2020; González De Molina and Lopez-Garcia, 2021; van der Ploeg, 2021; Place *et al*., 2022).

In terms of labour productivity, Tittonell *et al*. (2020) argue that in full transitions to agroecology at scale, productivity increases as a result of "process" intensification, extending the notion of intensification to include the "intellectual" inputs that characterize agroecology, such as managing landscape complexity, diversity, synergies, natural regulation, and ecosystem services. However, in any given context, farm labour productivity may increase, but less than for non-farm activities, leading farmers to feel poorer than others. What matters then is the difference between farm and non-farm labour productivity, which is approached in this foresight study using the "Labour Income Ratio" (see Section 2.3). In this NF/AE scenario, a particularly important objective is to **reduce farm–non-farm income inequalities**, and the following sections show under which assumptions and to what extent this can happen.

Going beyond the notions of labour productivity and income gap, attention was also given to the **sense of purpose and fulfilment** among farmers, with increased dedication. As farmers view their roles as integral to sustainable and regenerative practices, they would be willing to invest more effort and enthusiasm in their tasks, resulting in higher overall labour productivity.

Members of the Expert Group believed that this scenario would also make space for **greater participation of women** in the workforce for agriculture and small and medium enterprises, and for greater gender equality in asset ownership, visibility, agency and on decision-making power at all levels. In line with agroecology principles related to "participation"; "connectivity"; "social values and diets" and "fairness", active involvement of local women has been vital to the achievements of the APCNF initiative. Experts pointed out that APCNF is focused on women by definition through the women self-help group and, therefore, they assumed a low overall unemployment rate for the NF/AE scenario. This takes on greater importance as a possibility of the "re-employment" of women, when looking at the statistical trends in India (and Andhra Pradesh) showing women withdrawing from the workforce since 2005 (Mehrotra and Sinha, 2017; Siddiqui *et al*., 2017). Women's groups in the State have served as important platforms for social engagement, enabling collective efforts to drive change, improve local livelihoods, and foster community accountability. This existing social capital has played a key role in promoting trust and establishing strong relationships that facilitate the dissemination and adoption of natural farming methods.

The APCNF programme has observed a gradual shift from chemical to natural farming as women influence their spouses and male landowners, encouraging the transition on a yearly basis and plot by plot. It was reported by APCNF that higher levels of trust within a community correspond with greater agency among women farmers, as well as increased crop yields and improved environmental outcomes such as enhanced soil fertility and greater biodiversity. It was also noted that the empowerment of women through NF in Andhra Pradesh correlates with improved family planning, together with healthier working conditions (in terms of reduced exposure to agrochemicals), and biological on-farm efficiencies that decrease physical burden for women. Similarly, NF/AE is knowledge intensive and will give more interesting, knowledge-intensive and creative work to women.

In conclusion, this NF/AE scenario should provide opportunities to generate jobs and dignified agricultural employment resulting from the intensification of knowledge and labour, contributing to the social capital of farmers (gender empowerment, resilience, social cohesion and participation in natural resource governance), and thanks to opportunities to dynamize local markets and regenerate rural communities.

4.3.2 Assumptions in numbers

Table 5. Quantitative assumptions on population and employment for the 2050 natural farming scenario (capita)

	Assumptions for the NF/AE scenario in 2050	2019 (Mcap)	2050 (Mcap)	AGR (%)
Population	Forecast of KC, Wurzer, Speringer and Lutz (2018)	52.568	59.525	+ 0.40
20 to 64 year-old	Forecast of KC, Wurzer, Speringer and Lutz (2018)	32.544	35.349	+ 0.27
Employed	93% employment of the 20 to 64 year-old	22.406 (69%)	33.000 (93%)	+ 1.25
Employed in agriculture	30% of the employed persons	9.300 (42%)	10.000 (30%)	+ 0.23

Notes: NF – natural farming; AE – agroecology; Mcap – million capita; AGR – annual growth rate.

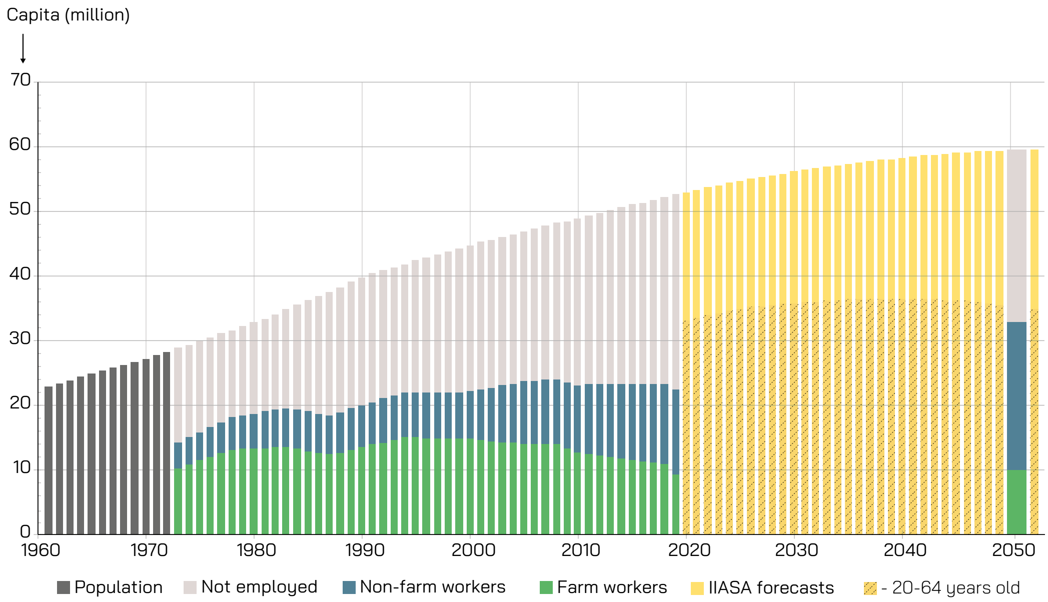
Population (total and 20 to 64 years-old) are based on KC, Wurzer, Speringer and Lutz 2018. Future population and human capital in heterogeneous India. Proceedings of the National Academy of Sciences, 115(33). Source: Dorin 2023.

Figure 34

Population in Andhra Pradesh 1961–2050 with the natural farming scenario

Note: IIASA – International Institute for Applied Systems Analysis (KC et al., 2018).

Source: Dorin, 2023.



4.4 ECONOMIC GROWTH

4.4.1 Main considerations from experts

In this NF/AE scenario for AP, a **significant higher annual growth rate** (AGR) **for the primary sector** (agriculture and allied activities) is envisioned compared to the past decades, i.e. **6** percent **on average** from 2019 to 2050 (32 years) against 4 percent from 1980 to 2019 (40 years).

This assumption made by the Expert Group is consistent with this NF scenario and its other assumptions for 2050:

- A **higher agricultural production through larger agricultural areas**, plus identical or even better yields than conventional industrial agriculture (e.g. Galab *et al.*, 2021; Kumar *et al.*, 2020; Duddigan *et al.*, 2023; GIST Impact, 2023), for multiple products on one farm as well as integration with livestock even at small farm level.
- A **better valuation of this agricultural production including premium prices on local, national and international markets** through labels such as "organic product", "natural food", "chemical-free food", "product from APCNF", "community-managed output", or even "robot-free food" or "job-creating food", etc.
- **Almost one-third of the active population involved in farming**, and well organized to influence how food is produced, processed, stored, transported, sold and consumed.
- Farmers who capture **additional added value by storing, processing or selling on their farm or through their collective organization**. As a result, farmers' income would improve, also as a result of labour and knowledge-intensive techniques and diversified activities.

This **higher growth in agriculture should in turn boost the overall economic growth of Andhra Pradesh, to 6.5** percent **per annum** on average from 2019 to 2050 (against 5.8 percent from 1980 to 2019). However, in this scenario which gives priority to farmers and a sustainable food system, the **economic growth of the non-farm sector would be lower than during the past decades: 6.7** percent from 2019 to 2050 against 7.25 percent from 1980 to 2019. The non-farm sector would reduce its share of the GDP while the agricultural share would be higher. This economic growth of the non-farm sector would nevertheless remain slightly higher than that of the farm sector (6.7 percent against 6.5 percent).

Experts recalled that **economic resilience** is fundamental in particular for small-scale producers, and so it would be accorded proper emphasis in this scenario. Diversified systems are often positively impact incomes, improve working conditions and enable resilient livelihoods, as increasingly demonstrated in studies (Stratton *et al.*, 2021; IPES-Food, 2016). Diversification is crucial for livelihood resilience; risk is a daily reality for many smallholder farmers. In this scenario, crop and livestock diversification inherent in NF/AE is seen as a form of insurance, allowing income to be stabilized in the face of crop failure or loss of livestock or other shocks and stresses (Gliessman *et al.*, 2007; Pellegrini and Tasciotti, 2014), contributing to overall livelihood resilience. Experts agreed that in NF/AE, agricultural risk would be lower given that increased crop and overall system resilience to biotic and abiotic shocks is much higher than in IA, resulting in lower crop insurance risk and thus input costs associated with it. It was also asserted that thanks to year-round production as well as reduced paid out costs of production, there would be lower chance of farmers going into debt in NF/AE.

Experts also reported that under NF/AE, by redesigning their production systems, farmers not only increase their intensity of work but also **improve work quality and occupational safety** due to non-exposure to toxic chemicals relative to conventional farmers. They also typically earn **higher net agricultural incomes** than conventional farmers, as mentioned earlier, by reducing input expenses and diversifying their markets and livelihoods. These observations, confirmed by some preliminary independent studies (Kumar *et al*., 2020; Galab *et al*., 2021; GIST Impact, 2023), highlight the potential for stable profits and improved working conditions under NF, as also for a vibrant growth of the agricultural value added in this NF/AE scenario. For example, GIST Impact (2023) evidenced that APCNF farmers saw an average 49 percent net increase in income; this was largely the result of a 44 percent (average) reduction in input costs – primarily fertilizers and pesticides.

It is thus foreseen that farmers would produce more food while improving the nutritional and health quality of produce (Bezner Kerr *et al*., 2021). This **high-quality produce** and the **low ecological and carbon footprint** of agroecological products would have a higher valuation, as mentioned earlier, due to consumers' increasing demand for ethically produced, chemical-free, and environmentally friendly products. The use of related quality labels would enhance consumer confidence, drive market demand, and support innovative price mechanisms for the products.

When addressing economic performance, the marketing and consumption dimension should be considered together with production aspects, including **fair and transparent price** setting mechanisms (how value is distributed among food system actors) and the promotion of **short value chains** that empower small producers and small businesses. In the words of members of the Expert Group, this NF/AE scenario would put emphasis on local development and small farmers, producers, business, everywhere. It would enable increased transparency in marketing schemes and more just, fair, and participatory price settings (FAO and INRAE 2020). In fact, highly diversified and healthy produce of NF/AE can drive institutional innovations impacting local and regional economies. One such innovation would be the diversification and creation of new food market channels and networks: farmers would pursue direct sales to consumers through farmers' markets, community-supported agriculture, and online platforms. Cooperative networks and value-added processing would facilitate entry into retail and export markets. This would enhance market resilience and reduce dependence on a single market, and thus contributing to the overall economic stability of the food system. These new market networks, because of the growing awareness of the health and environmental aspects of agriculture, would support new values and meanings for food, as attention would be drawn to questions related to equity, fairness, sovereignty, governance, social participation and sustainability (Loconto *et al*., 2018).

The need to increase **consumer awareness** regarding the type, quality and safety of food to consume, and the sustainability of related production and distribution processes, is underlined as a trigger to move agri-food systems towards sustainability (FAO, 2023). This NF/AE scenario offers opportunities for governments, researchers and farmer organizations, to foster awareness campaigns and consumer education initiatives to highlight the benefits of natural farming practices, increase demand for natural food and create new opportunities for farmers.

Some experts also pointed that in this NF/AE scenario, there is a need to think of farmers as being in both the primary and service sector, to consider the **environment or ecosystem services** that farmers can produce for local to global societies in terms of reversing climate change and the degradation of water and other natural resources. Farmers could receive remuneration for contributing to human and environmental health (like doctors), which could also increase farmers' recognition and youth interest. Payment shouldn't then be per hectare but per farmer, and according to their practices and the multiple environmental benefits they provide.

It was assumed that **income redistribution** under the NF/AE scenario would favour smallholder households because of intensified labour absorption and integration of livestock rearing. This should be in addition to reduced input costs, improved/stable crop yields, market demand for sustainable produce, access to diversified markets, and the empowerment of smallholder farmers. Furthermore, the emphasis on community cooperation, inclusive decision-making, and resilience to market fluctuations would contribute to a more equitable distribution of income between farm and non-farm workers, but also within the farming sector and rural communities. It would help make the current situation in Andhra Pradesh more equitable: according to NSO (2021) in 2018–19, the average monthly net income of Andhra's agricultural households possessing 1 to 2 ha was about INR 8 600 (with less than 30 percent from crop production), about two times less than those possessing 4 to 10 ha (with more than 60 percent from crop production).

However, many experts also felt the need to re-think and measure wealth in a broader sense, going beyond income level and distribution, and considering dimensions of human and ecosystem health, wellbeing and peace. For example, GIST Impact (2023) showed strong correlation between **lower on-farm health risks** and transitions to APCNF farming; farmers on APCNF farms lost one-third fewer working days to illness, compared with farms using counterfactual farming methods. The health-cost analysis, based on health expenses incurred and wages lost from illness, showed that villages with chemically intensive farming had the highest health costs, 26 percent higher than those for APCNF farmers in the region. The use of chemical pesticides and fertilizers correlated with a higher incidence of short-term exposure and symptoms, which in turn correlated with higher health costs and productivity losses for farmers. Such health impacts are not accounted for in conventional market-based crop-pricing models. At the same time, household dietary diversity was greater in APCNF households than in other conventional farming households, indicating access to a greater variety of crops (GIST Impact, 2023).

Special consideration was given to the notion of "**farmer dignity**" inherent in NF/AE, which reinforces their decision-making skills and creativity, autonomy, health and sense of purpose in creating positive impacts on their lives and ecosystems. One participant described the aspirational "economy and people's lifestyle" aspect of this scenario as: "people pursuing life with a sense of purpose; simple living; widespread pursuit of conserving nature; decentralized informal production entities; and social justice and ethics governing society". Here again, GIST Impact (2023) showed that APCNF led to **increased social capital** in villages including: information sharing, mutuality, collective action, trust and support, community cohesion, and risk reduction. Increasing the social capital creates a "virtuous cycle" of increased economic gains, which in turn led to greater trust, cohesion, and reciprocity. Women significantly influence this social capital, particularly knowledge sharing, community cohesion, trust and mutual support.

Experts also recalled that in India, organic agriculture, agroecology and natural farming are increasing, with very limited government support, as compared to the public human and financial resources invested in conventional agriculture. Industrial agriculture is massively supported through subsidies, road infrastructure, research and national market infrastructure rather than local markets. Experts suggested that this lack of a level playing field should be considered when comparing the performance and metrics of both scenarios. At the same time, the promising performances observed so far in NF/AE, show great potential in the future for scaling up and out hugely if they received specific and targeted policy and financial support.

Overall, experts stressed that prioritizing farmers and sustainable food systems can boost the economic growth of Andhra Pradesh, with fair pricing mechanisms, transparent value distribution, market diversification and short value chains that empower small-scale producers and businesses. Wealth redistribution and regeneration of ecosystems should be considered alongside income distribution. Finally, it is essential to address the lack of a level playing field, where conventional agriculture receives extensive support compared to natural farming and agroecology.

4.4.2 Assumptions in numbers

Table 6. Quantitative assumptions on economic growth for the 2050 natural farming scenario

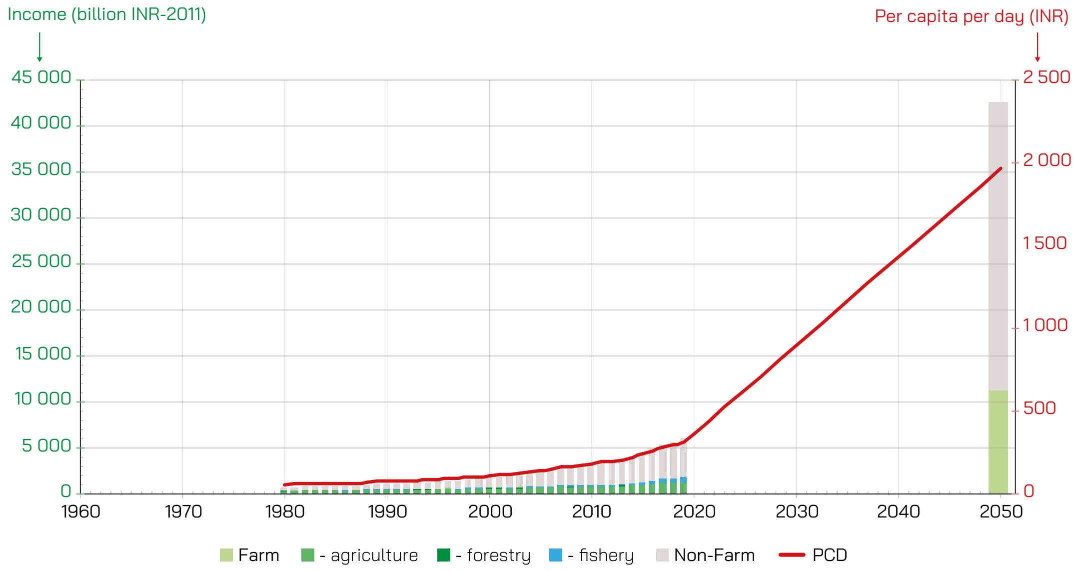
	Assumptions for the NF/AE scenario in 2050	2019 (TINR)	2050 (TINR)	AGR (%)
GVA	+ 6.50 % per year on average from 2019	6.058	42.672	6.50
GVA farm	+ 6.00 % per year on average from 2019	1.846 (30%)	11.240 (26%)	6.00
GVA non-farm	+ 6.70 % per year on average from 2019 (deducted from above)	4.211 (70%)	31.432 (74%)	6.70

Note: GVA – gross value added; NF – natural farming; AE – agroecology; TINR = Tera INR = 10^{12}; AGR – annual growth rate. Source: Dorin, 2023.

Figure 35

Economic growth in Andhra Pradesh 1980–2050 with the natural farming scenario

Source: Dorin, 2023.



4.5. FOOD YIELD AND PRODUCTION

4.5.1. Main considerations from experts

In this NF/AE scenario for AP, an average **caloric food yield of 36 000 kcal/ha/day** (Figure 36) is envisioned in 2050. With the assumptions about cultivated areas for this scenario (Section 4.2), this would lead to a total **production of 298 Gkcal/day**, or around **5 000 kcal/capita/day** (Figure 37) with the projections of total population in 2050 (Section 3.2 and 4.3).

Table 7 details how experts arrived at these numbers – and how production, area and yield are intertwined – by dividing the State into three agroclimatic subregions, and assuming a breakdown of cultivated area and yield by subregion for 2019 then 2050. For example, it was assumed that the current high-yield of the Godavari-type subregion would decrease by 7 percent between 2019 and 2050 because of better balanced plant production with water-efficient and chemical-free Natural Farming. In contrast, in the current low-yield Anantapur-type subregion, the annual yield (expressed in kcal/day) is expected to increase significantly due to a shift from 1 to 2–3 cropping seasons (i.e. increase in cropping intensity with the 365-day plant cover of Natural Farming). We have also used the fallow areas by subregions in 2019 (not presented here) to dispatch the new cultivated areas assumed in this NF/AE scenario (Section 4.2).

The assumption made on yield for 2050 was a compromise between the following considerations:

- With Natural Farming, for almost all crops, there is **no yield penalty** and even higher yields than with conventional industrial agriculture or organic agriculture, as independent studies increasingly show (Kumar *et al*., 2020; Galab *et al*., 2021; Duddigan *et al*., 2023; GIST Impact, 2023); for example, GIST Impact (2023) showed that the yields of prime crops (paddy rice, maize, millet, finger millet, and red gram) increased by an average 11 percent in APCNF villages.
- Above all, the **crop intensity in all rained areas should be multiplied by 2 or 3** times (with PMDS, 365-day plant cover, etc.), which should in turn boost the yield (annual production divided by the net cultivated area) on these major agricultural areas of Andhra Pradesh. With Natural Farming, however, food production would have lower caloric value than conventional industrial crops, as natural foods have a better **balance of carbohydrates, proteins and fats as well as fibre and micronutrients** (Baranski *et al*., 2014; Benbrook *et al*., 2008; Worthington, 2001).

Table 7. Quantitative assumptions on area, yield and production for three subregions for the natural farming scenario (2019, 2050)

	Cultivated area		Yield	Production	
	1 000 ha	%	kcal/ha/day	Gkcal/day	kcal/cap/day
2019 (April 2019 – March 2020)					
Andhra Pradesh (13 districts)	6 200	100	31 095	192	3 660
• Godaveri type (6 coastal districts)	2 845	46	45 000	128	
• Middle type (3 tribal/plain districts)	876	14	31 000	27	
• Anantapur type (4 semi-arid districts)	2 479	40	15 000	37	
2050 (NF/AE scenario)					
Andhra Pradesh (13 districts)	8 280	100	36 000	298	5 008
• Godaveri type (6 coastal districts)	3 680	44	42 000	155	
• Middle type (3 tribal/plain districts)	1 103	13	35 000	39	
• Anantapur type (4 semi-arid districts)	3 497	42	30 000	105	

Note: kcal – kilocalories; Gkcal – gigacalories; NF – natural farming; AE – agroecology. Source: Dorin, 2023.

- Moreover, in this NF/AE scenario, a significant part of the expansion of plant production would be done on fallow and even barren lands regenerated by Natural Farming (see assumptions on land use in Section 4.2), and it may take longer than expected to turn this land into highly productive living soils.

Experts expressed that the use of chemical fertilizers that are applied in conventional intensive Indian agriculture is unbalanced and efficiency decreases (i.e. decreasing marginal productivity). Decreasing yields in food production are now seen even when ever-increasing amounts of fertilizer is applied. It can be expected that continuing the conventional intensification path would entail "one kilogram of fertilizer applied for each kilogram of food produced", with multiple consequences on climate change and food security (Altieri and Nicholls, 2012).

In this same line, the experience from the past few decades shows that in India, production and yield growth rates for major crops have declined. This is because the scope for increasing the net sown area is limited, and unsustainable practices have led to soil degradation in the form of soil fertility depletion, erosion, and waterlogging. Also, the rate of expansion of surface irrigation has decreased and there has been a drop in the water table. Experts agreed that the NF/AE scenario represents an opportunity for Andhra Pradesh to regenerate soil health and productivity. In addition, healthier soils with a higher amount of organic matter allow for maintaining more water available for crops, as well as improving the infiltration of excess water, among other beneficial effects for the agroecosystem (Bhadha *et al.*, 2017; Zimnicki *et al.*, 2020). The analysis conducted by independent assessments for APCNF farms shows improvements in the efficiencies of all paddy farmers, noting that it has increased from 0.6962 in 2018–19 to 0.9580 in 2019–20, in all districts in the state and across all farm categories (Galab *et al.*, 2021).

Current food and nutrition challenges in India emphasize, when analysing food security, the importance of considering the nutritional content of food production, and their balanced accessibility for the poorest consumers (Section 3.4). With the NF/AE scenario based on highly diversified food production, the current gap in nutritional security should be greatly improved. Indeed, this scenario embodies a transformative approach to all the dimensions of food and nutrition security. Diverse cropping patterns and agroecological practices guarantee a nutritious food supply (Bezner Kerr *et al.*, 2021). Promoting local produce and reducing food miles enhances accessibility for all communities. Crop diversification strengthens food utilization, providing balanced and nutrient-rich diets. Regenerative farming ensures stable food production despite climate change, preserving soil health and biodiversity for sustainability. Nutrient-dense produce combats deficiencies, promoting better health. Empowering farming communities through knowledge exchange and collective decision-making enhances the resilience of the food system, enabling timely adaptation to challenges and uncertainties. Fair market access and prices for farmers foster equity and inclusivity, ensuring that the benefits of food production are shared equitably among all stakeholders. With a chemical-free agriculture, the food safety and health should also be much better guaranteed than it is today, as pesticides have become a major health issue in India for both producers and consumers (EPW, 2017a; Bonvoisin *et al.*, 2020; Donthi, 2021).

4.5.2 Assumptions in numbers

Table 8. Quantitative assumptions on yield for the 2050 natural farming scenario

	Assumptions for the NF/AE scenario in 2050	2019 (kcal/ha/day)	2050 (kcal/ha/day)	AGR (%)
Yield	High yield in balanced food 365 days per year	31 095	36 000	+ 0.47

Note: AE – agroecology; NF – natural farming; kcal – chilo calories. Source: Dorin, 2023.

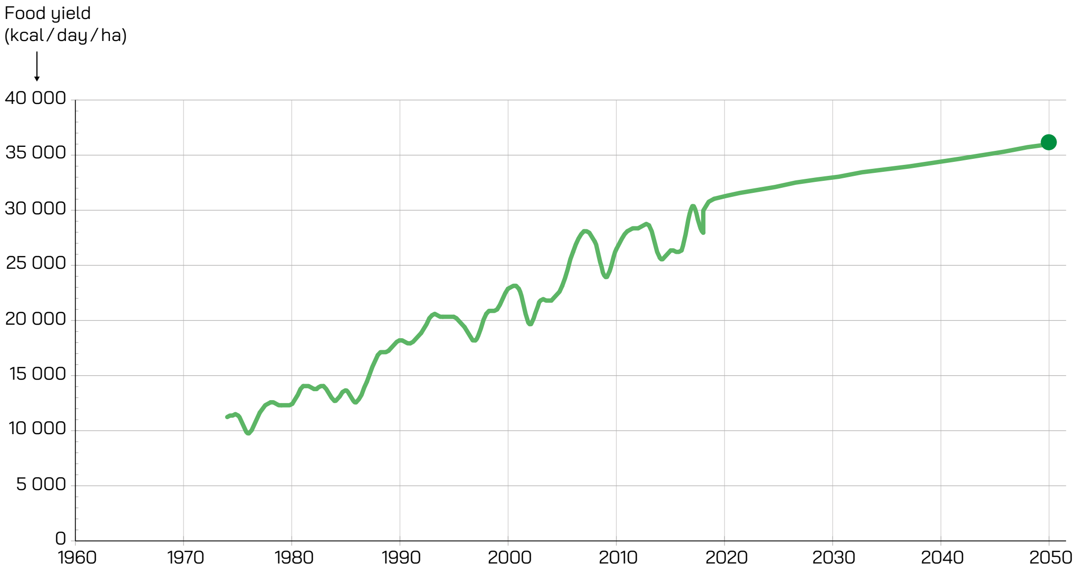


Figure 36

Caloric plant food yield per hectare in Andhra Pradesh 1973–2050 with the natural farming scenario

Source: Dorin, 2023.

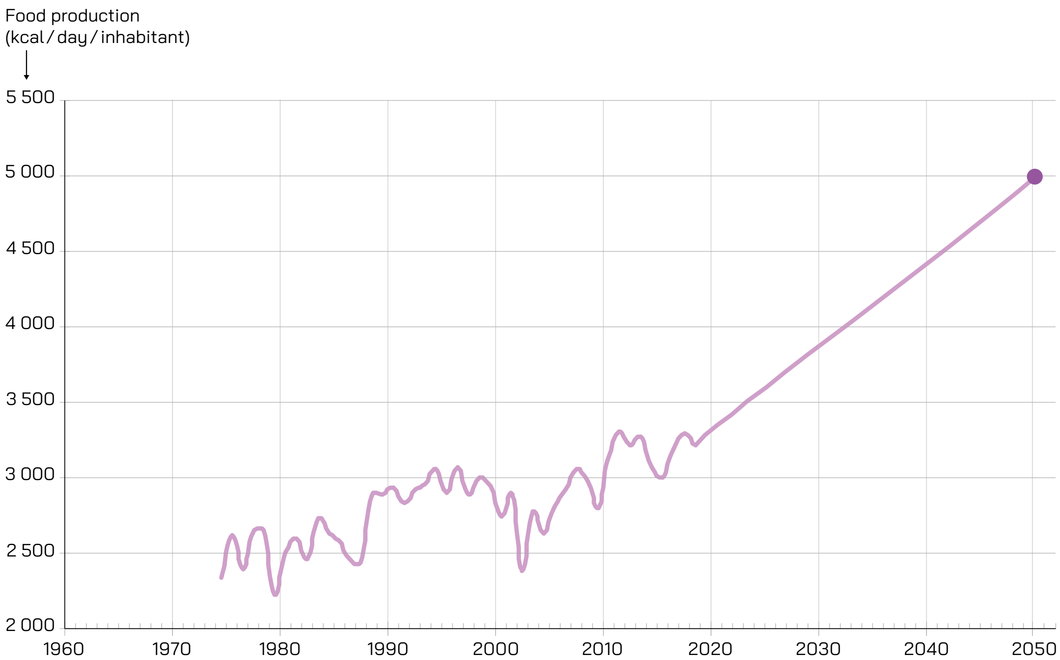


Figure 37

Caloric plant food production per capita in Andhra Pradesh 1973–2050 with the natural farming scenario

Source: Dorin, 2023.

5. Scenario of Industrial Agriculture (IA) in 2050

5.1 GENERAL PRINCIPLES

The following general principles of the IA scenario emerged from discussions of the seven virtual expert workshops that took place prior to the in-person workshop in Anantapur:

> ***Consumerism-oriented society based on capital-intensive technology, fossil energy and robots, highly dependent on international trade and price competition, with standardization and mass-production of few food products, laboratory genetic and chemical inputs in agriculture, highly processed or fortified food, and centralized R&D tending towards a "World Without Agriculture" (less than 3 percent of employment and 3 percent of GDP in agriculture) typical of the OECD "modern economic growth" path.***

The following sections present how these general principles were translated into quantitative assumptions by the Expert Group at the Anantapur workshop, within a process that also checked the overall consistency of these assumptions across different domains, from land use to economic inequality.

5.2 LAND USE

5.2.1 Main considerations from experts

In this IA scenario for AP in 2050, the rationale of industrial agriculture and the Green Revolution would be deepened further. This "**commodity-centric vision"** (Shah, 2021) is focused on mass production and standardization a of few agricultural products. In this approach, IA seeks to develop genetics with high yield potential under ideal development conditions that we seek to transfer from the laboratory to the field, unlike agroecology which seeks the genetics that are best expressed in synergy with multiple surrounding other species and with the multiple characteristics and needs of the socioagroecosystem where it is grown (Rosset and Altieri, 1997; Guzmán *et al.*, 2018; Dorin, 2022). The costs of this IA form of production are high because of the need to recreate the ideal laboratory conditions with correct doses of water, fertilizer, pesticides (and/or nutrients and antibiotics for animals) and other inputs whose costs are in fact amortized through economies of scale (the larger the farm, the better) and the use of machinery and robots (Dorin, 2022; Ikerd, 2023).

Such a strategy is known to be "land sparing" (without taking into account any "rebound effect": see Desquilbet *et al.*, 2017 for more details), i.e. it saves agriculture land in favour of forests, biodiversity and "wild nature" (e.g. Borlaug, 1987; Waggoner, 1996; Avery, 1997; Borlaug, 2002; Green *et al.*, 2005). The most extreme form of realization of this strategy could be, in the long run, soilless hydroponic or aeroponic agriculture (Dorin, 2022) including for animal protein production through, for example, specialized insect farming (Verner *et al.*, 2021).

This theory of **high-input, high-yield and land-sparing (but capital-intensive) agriculture** has been partially verified with the industrialization of Andhra's agriculture: from 1970 to 2017, the net cultivated area decreased (-0.20 percent per annum on average) as well as the net pasture area (-1.60 percent), while the fallow area increased (+0.62 percent). But the forest-and-shrub area also slightly decreased (- 0.11 percent) instead of increasing.

Based on these past evolutions, the experts assumed that in the IA scenario for 2050, **fallow land would continue to increase** at the same average rate as during the last half-century, to the detriment of

cropped land, which would decrease also because of the extension of urbanized areas (+0.25 percent per annum as in the NF/AE scenario). Some experts noted that in this scenario, the rate of urbanization could be higher than already observed in Haryana and Uttar Pradesh, where farmers sold their fertile land due to the development of reals estate for cities such as Gurgaon and Noida (Singh and Singh, 2013; Sundar *et al.*, 2015; Firdaus, 2021).

All other areas (pasture, shrub, forest, barren) would remain the same and even be highly protected in 2050 as "natural sanctuaries" or "carbon sinks" with or without carbon bonds (Estrada-Chavira, 2022). At the same time, the **best agricultural land would be further intensified** with the frontier technologies of industrial agriculture wherever capital or subsidies are available to deploy them. This would most probably lead to further exploitation of agricultural soils and groundwater, but allow each district to specialize in a few export-oriented and price-competitive commodities (e.g. rice, maize, sugarcane, sunflower, groundnut, palm oil, mango, banana, chili, tobacco, cotton, poultry, shrimp). These projections are expected if there is no energy price crisis nor an abrupt acceleration in the increase of the global average temperature, as well as other phenomena associated with climate change.

Finally, experts expressed that another expected modification in AP land structure by 2050 has to do with the number of farmers and farms. The current trend of decreasing number of farmers (Section 3.2) would continue in the IA scenario along with land concentration. Small-marginal farmers who could ill afford the capital intensity would be eased out, either through reverse tenancy in favour of large farmers or corporate entities, or through outright selling of lands to meet their debts or seek alternative livelihoods.

5.2.2 Assumptions in numbers

Table 9. Quantitative assumptions on land use for the 2050 industrial agriculture scenario

	Assumptions for the IA scenario in 2050	2019 (Kha)	2050 (Kha)	AGR (%)
Area		16 297	16 297	
Cultivated (annual crops and plantations)	Hectares in 2019 – increase in fallow lands – expansion of urbanized areas	6 203	5 503	– 0.39
- irrigated	Hectare in 2019 (net area)	2 763 (45%)	2 763 (50%)	
Pasture	Hectares in 2019	209	209	
Fallow	Hectares in 2019 + 0.62% per year (trend 1970–2017) from 2017	2 383	2 918	+ 0.66
Shrub	Hectares in 2019	414	414	
Forest	Hectares in 2017	3 688	3 689	
Barren	Hectares in 2017	1 345	1 345	
Urban	Hectares in 2019 + 8%	2 055	2 219	+ 0.25

Note: 2019 figures are 2017 figures due to unavailable official land-use statistics beyond 2017 in India (October 2021); IA – industrial agriculture; Kha – thousand hectares; AGR – annual growth rate. Source: Dorin, 2023.

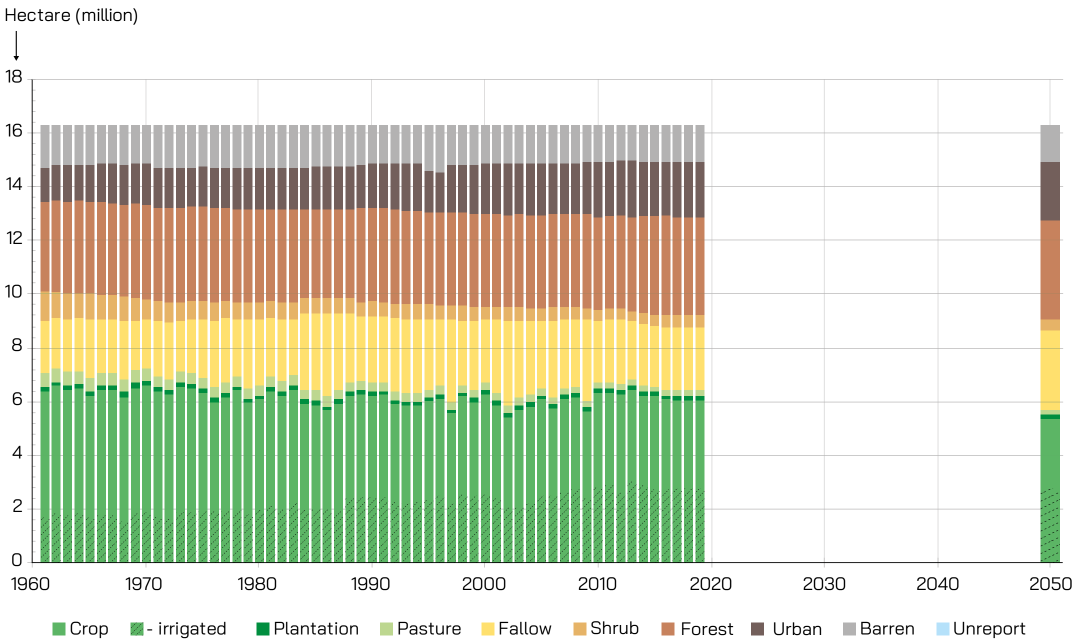


Figure 38

Land use in Andhra Pradesh 1961-2050 with the Industrial Agriculture scenario

Source: Dorin, 2023.

5.3 POPULATION AND EMPLOYMENT

5.3.1 Main considerations from experts

In this IA scenario, as in the NF/AE scenario, the Andhra population would increase as modelled by K.C. *et al*. (2018), with almost **60 million inhabitants in 2050** (against 52.6 in 2019). Similarly, the **population aged 20 to 64 would reach more than 35 million persons in 2050** (against 32.5 in 2019). It could be argued that these population projections should show a difference between the two scenarios, if these scenarios are different in terms of income, health, inequality, urbanization, etc., which attracts or repels emigration from other states in India. It is obviously true (especially with likely future migrations from the more populous and poor northern states to wealthier states in southern India), but would then imply evaluating, among other things, the impact of such variables on inter-state migration, as well as their value in all the other India states, which remains well beyond the ambitions of our foresight exercise. Moreover, maintaining identical population projections, between the two scenarios, allows a fair comparison of their performance, which would otherwise be biased by different demographics.

If the demographics are identical between the two scenarios, it is not the case for employment. In this IA scenario, it was assumed that **a significant portion of the 20 to 64 year-olds would remain unemployed as in 2019** (30 percent) because of the continued automation of human activities (machineries, robots, artificial intelligence, etc.) in all economic sectors.

Furthermore, **of those employed, fewer would work in agriculture and allied activities: 20 percent in 2050** against 42 percent in 2019, a decline in the rate (-2 percent per annum) which has never been seen in the history of Andhra. Indeed, marginal and **small cultivators would have disappeared in great numbers** due to indebtedness (and sometimes suicide) as in the past (Sridhar, 2006; Nagaraj *et al*., 2014; RSV, 2018), since public policies, corporations and markets would encourage input-intensive agriculture (with genetically modified organisms [GMO], groundwater, synthetic fertilizers, pesticides, insurances, data, internet, etc.) and capital-intensive monocultures (with machinery, computers and robots to save labour and inputs) which are beyond their means. This automation of jobs, particularly in agriculture, would then follow a trend similar to that observed during recent decades in OECD countries (Arntz *et al*., 2016; Dorin, 2022; Ikerd, 2023) and more recently in India (Mehta *et al*., 2014).

Many **landless agricultural labourers are also projected to leave agriculture** as a result of these capital-intensive, energy-intensive and labour-saving technologies that many call for to solve the food and environmental crisis (Lenain *et al.*, 2021; Wolfert *et al.*, 2021; Mehrotra, 2021). In this IA scenario, some of these small or landless farmers (and/or their children) would find employment in large agro-industries, food distributors, digital companies and other businesses if appropriate public schemes help them to orient their skills, abilities and techniques to the demand of national and international markets. But it may be in numbers far below employment needs, which would then amplify the overall "jobless growth" of India since the 2000s (EPW, 2010). With migration to cities to find new employment opportunities, this would also accelerate the rate of urbanization and most probably the prevalence of slums or low-cost housing areas, as already shown for Delhi or Bangalore (Acharya *et al.*, 2017; Pottinger-Glass and Pfeffer, 2021).

Finally, regarding the situation of women in the IA scenario in 2050, it can be expected that in the absence of active transformative measures, **the current trend of women withdrawing from the labour market will continue.**

5.3.2 Assumptions in numbers

Table 10. Quantitative assumptions on population and employment for the 2050 industrial scenario

	Assumptions for the IA scenario in 2050	2019 (Mcap)	2050 (Mcap)	AGR (%)
Population	Forecast of KC, Wurzer, Speringer and Lutz (2018)	52 568	59 525	+ 0.40
20 to 64 year-old	Forecast of KC, Wurzer, Speringer and Lutz (2018)	32 544	35 349	+ 0.27
Employed	30% employment of the 20 to 64 year-old	22 406 (69%)	24 762 (69%)	+ 0.32
Employed in agriculture	20% of the employed persons	9 300 (42%)	4 953 (20%)	– 2.01

Note: IA – industrial agriculture; Mcap – million capita; AGR – annual growth rate

Population (total and 20 to 64 year-old) are based on KC, Wurzer, Speringer & Lutz 2018. Future population and human capital in heterogeneous India. Proceedings of the National Academy of Sciences, 115(33). Source: Dorin 2023.

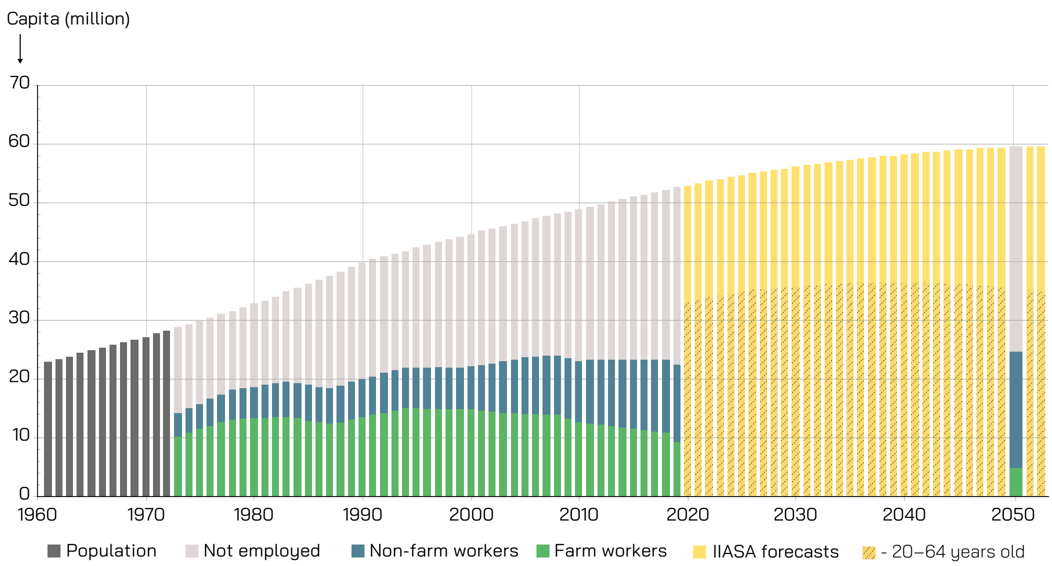


Figure 39

Population in Andhra Pradesh 1961–2050 with the Industrial Agriculture scenario

Note: IIASA – International Institute for Applied Systems Analysis (KC et al., 2018).

Source: Dorin, 2023.

5.4 ECONOMIC GROWTH

5.4.1 Main considerations from experts

In this IA scenario for AP in 2050, the **annual growth rate of 6.71** percent **of the non-agricultural sector would be almost the same as for the NF/AE scenario** (**6.7** percent). In contrast, the annual growth rate of the **agricultural sector for the IA scenario would fall to 3.50** percent (6 percent in the NF/AE scenario), i.e. even below Andhra's 1980–2019 trend (4 percent). Overall, the economic growth rate of Andhra Pradesh from 2019 to 2050 would then be 6 percent per annum on average (with higher rates in the 2020s than in the 2040s as in the NF/AE scenario), a half point lower than in NF/AE scenario (6.5 percent per annum).

These assumptions were made by the Expert Group in line with the following points of this IA scenario:

- A large section (30 percent) of the 20 to 64 age group would be unemployed (about 10.6 million out of 35.4 in 2050) and would therefore have low or no purchasing power, which should significantly impact the overall demand and growth in monetary terms.
- People employed in agriculture (20 percent, i.e. less than 5 million adults in 2050) should generate a modest total added value due to:
  - less cultivated land (5.5 million ha against almost 8.3 in the NF/AE scenario);
  - high cost of cultivation (lab-genetics, irrigation, fertilizers, pesticides, machinery, robotics, credit, insurance, etc.), similarly to those currently faced by farmers in OECD countries;
  - increasing reliance on fossil energy embedded in inputs and machineries (Harchaoui and Chatzimpiros, 2018), the price of which is likely to rise sharply in the coming decades;
  - low farm gate prices of export-oriented, standardized biomasses, which are valorized downstream of the agricultural sector by large agrifood and distribution industries;
  - high frequency of production failures with low resilience of monocropping or other specialized agricultural productions to biotic and abiotic disturbances (pest and diseases, extreme weather events due to climate change, soaring fossil energy prices);
  - overall declining productivity of the natural capital (soil, water, agro-biodiversity), aggravated by climate change (Jägermeyr *et al.*, 2021; Patel *et al.*, 2022).

Experts indicated that, in the IA scenario, low farm gate prices are expected, given that farmers are highly specialized, tending to monocultures, and have a low bargaining power compared to exporting and trading companies, which are the ones who set the prices.

Participants in the Expert Group summarized this economic industrial scenario as: "Capital intensive, with significant foreign investment and investments from domestic corporates, focused on large-scale manufacturing (in specialized economic zones) as well as urban and business-support services; and services in the lifestyle and hospitality sectors. The economy would be capital-intensive with pan-India and export-oriented agricultural markets. There would be extensive farm/district specialization, and agriculture would privilege monocultures based on lab-genetics and artificial intelligence, and would be chemical intensive, water intensive, and largely mechanized and digitalized. Productivity of monocrops per hectare would still be the key metric used to measure agricultural output".

5.4.2 Assumptions in numbers

Table 11. Quantitative assumptions on economic growth for the 2050 industrial agriculture scenario

	Assumptions for the IA scenario in 2050	2019 (TINR)	2050 (TINR)	AGR (%)
Total GVA	+ 6.00% per year on average from 2019	6.058	36.88	+ 6.00
GVA farm	+ 3.50% per year on average from 2019	1.846 (30%)	5.364 (15%)	+ 3.50
GVA non-farm	+ 6.71% per year on average from 2019 (deducted from above)	4.211 (70%)	31.517 (85%)	+ 6.71

Note: IA – industrial agriculture; TINR= Tera INR = 10^{12} Indian rupees; GVA: gross value added; AGR – annual growth rate. Source: Dorin, 2023.

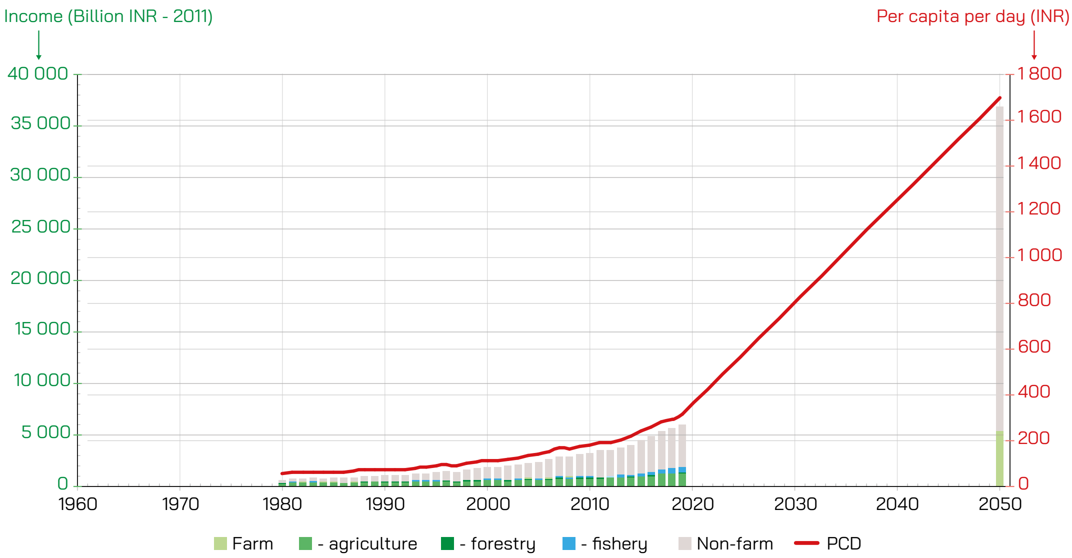


Figure 40

Economic growth in Andhra Pradesh 1980–2050 with the industrial agriculture scenario

Source: Dorin, 2023.

5.5 FOOD YIELD AND PRODUCTION

5.5.1 Main considerations from experts

In this IA scenario for AP, an average caloric food yield of around **43 855 kcal/ha/day** is expected in 2050, which would prolong past trends whatever the costs (Figure 41), and be 41 percent more than in 2019 and 22 percent more than the NF/AE scenario. However, with the assumption made of reduced cultivated areas in this scenario (Section 5.2), this would lead to a total State **production of 241 Gkcal/day, or 4 050 kcal/capita/day** (Figure 42) with the projections of total population in 2050 (Sections 3.2 and 5.3). This production per capita would then be slightly more than in 2019 but significantly less than in the NF/AE scenario for 2050 despite a higher average yield. Table 12 details how we arrived at these numbers – and how production, area and yield are intertwined – by dividing the State into three agroclimatic subregions, and assuming a breakdown of cultivated area and yield by subregion for 2019 then 2050. Obviously the large rainfed area (Anantapur's type) would be the most affected by the reduction in cultivated area, for lack of profitability and economic risk of cultivating land without irrigation and a single cropping season, as well as no affordable technology nor economic incentives to maintain and develop rainfed agriculture in this IA scenario.

The assumption made on yield for 2050 was a compromise between the two following considerations.

- During 10 years, from 2006 to 2016, food yield in Andhra Pradesh stagnated at around 27 000 kcal/ha/day (Figure 32), which could illustrate the reaching of the limits of the intensive model of industrial production, with the combined effects of factors such as:
  - the overexploitation and depletion of natural factors of production, particularly soil and water;
  - a decline in the marginal productivity of conventional industrial factors of production when they are overused (high-yielding varieties, irrigation, fertilizer, pesticides, etc.);
  - more crop failure and greater exposure of monocultures to biotic and abiotic shocks, the frequency of which is expected to be higher in the future (drought, flood, pest and diseases, increase in oil prices, etc.).

Table 12. Quantitative assumptions on area, yield and production in three subregions for the industrial agriculture scenario (2019, 2050)

	Cultivated area		Yield kcal/ha/day	Production Gkcal/day	kcal/cap/day
	1 000 ha	%			
2019 (April 2019 – March 2020)					
Andhra Pradesh (13 districts)	6 200	100	31 095	192	3 660
• Godaveri type (6 coastal districts)	2 845	46	45 000	128	
• Middle type (3 tribal/plain districts)	876	14	31 000	27	
• Anantapur type (4 semi-arid districts)	2 479	40	15 000	37	
2050 (**IA scenario**)					
Andhra Pradesh (13 districts)	5 500	100	43 854	241	4 052
• Godaveri type (6 coastal districts)	2 845	52	60 000	171	
• Middle type (3 tribal/plain districts)	876	16	50 000	44	
• Anantapur type (4 semi-arid districts)	1 779	32	15 000	27	

Notes: kcal – kilocalorie; Gkcal – gigakilocalories. Source: Dorin, 2023.

Imagining high industrial yields in 2050, therefore, seems very daring. It would be ignoring planetary limitations and their link to the state of soils, fossil energy, water, etc. (Rockstrom *et al.*, 2009), especially in land-constrained countries such as India where the intensive use of agro-industrial inputs has been incentivized and has become widespread.

- On the other hand, in this IA scenario, the area of cultivated land would continue to decrease with almost all the decline confined to rainfed zones (see assumptions on land use in **Section 5.2**). But the focus is on the best irrigated land where crop intensity and annual yield are higher, and with a rotation of monocultures for which R&D would continue to propose technological innovations to increase their yield while limiting the use of conventional inputs (with precision and/or digital agriculture, genomics, etc.). The prospect of a higher average annual calorie yield in 2050 than at the end of the 2010s is therefore also perfectly conceivable in this AI scenario. All the more so since it was already the case at the end of the 2010s in the neighbouring state of Tamil Nadu, with an average yield of 55 000 kcal/ha/day, of which more than 50 percent comes from strong specialization in the production of high-calorie oilseeds (26 percent only in Andhra at the same period).

Another factor to be taken into account in the yield assumption for this IA scenario is that, as mentioned above, agricultural land would be saved but accompanied by the development of capital-intensive technologies (e.g. hydroponics, robots) with costly inputs (e.g. genomics, pesticides) requiring large-scale farms to be amortized, as is the case in most OECD countries (Dutia, 2014), but not in India even in 2050 with this IA scenario. Within this IA scenario, the gross value added per hectare would in fact be rather low and also pulled down due to low farm-gate prices for standardized products intended for national and international food and non-food markets. All this should therefore curb the adoption of these high-yielding industrial technologies, and therefore limit the growth of the yield by 2050.

Some experts indicated that, although efficiency advances can be observed with new industrial technologies, it is not enough to guarantee their viability in a future of climate change and fossil energy crisis. Furthermore, it seems bold to many to build a scenario on yields in 2050 based on technological breakthroughs that do not exist yet, but would solve all major challenges in the future. In conclusion, they formulated a moderate yield increase assumption for 2050 for the industrial scenario (i.e. lower than the past linear trends over 1973–2019), and reasoned that the 2050 yield in the NF/AE scenario is based on currently available technologies, and not on non-existent and, most likely, costly future technologies under the IA paradigm.

5.5.2 Assumptions in numbers

Table 13. Quantitative assumptions on yield for the 2050 industrial agriculture scenario

	Assumptions for the IA scenario in 2050	2019 (kcal/ha/day)	2050 (kcal/ha/day)	AGR (%)
Yield	Higher yield whatever the cost, except for rainfed	31 095	43 855	+ 1.12

Note: IA – industrial agriculture; AGR – annual growth rate. Source: Dorin, 2023.

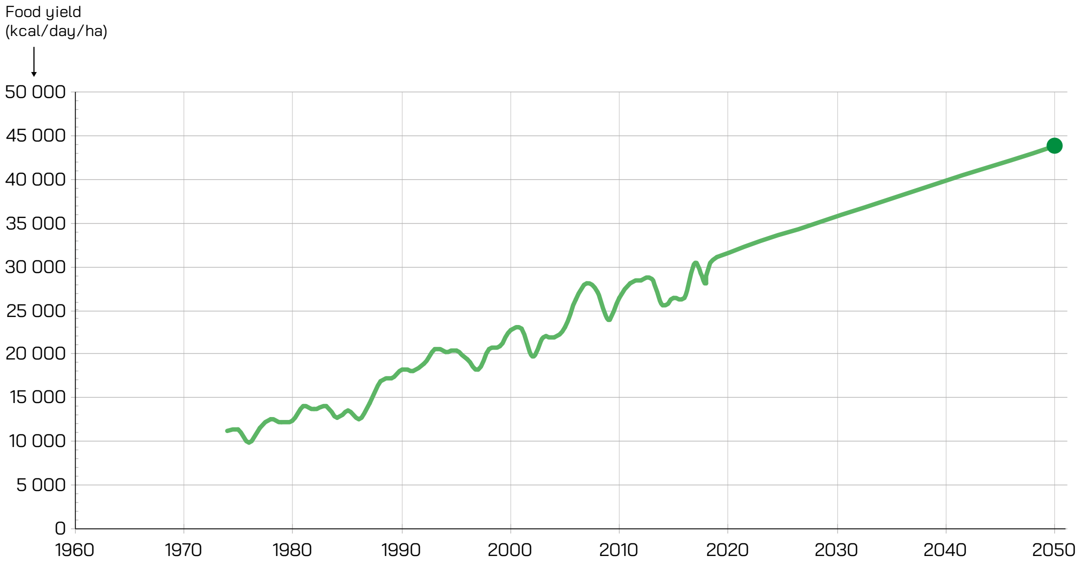


Figure 41

Caloric plant food yield per hectare in Andhra Pradesh 1973–2050 with the industrial agriculture scenario

Source: Dorin, 2023.

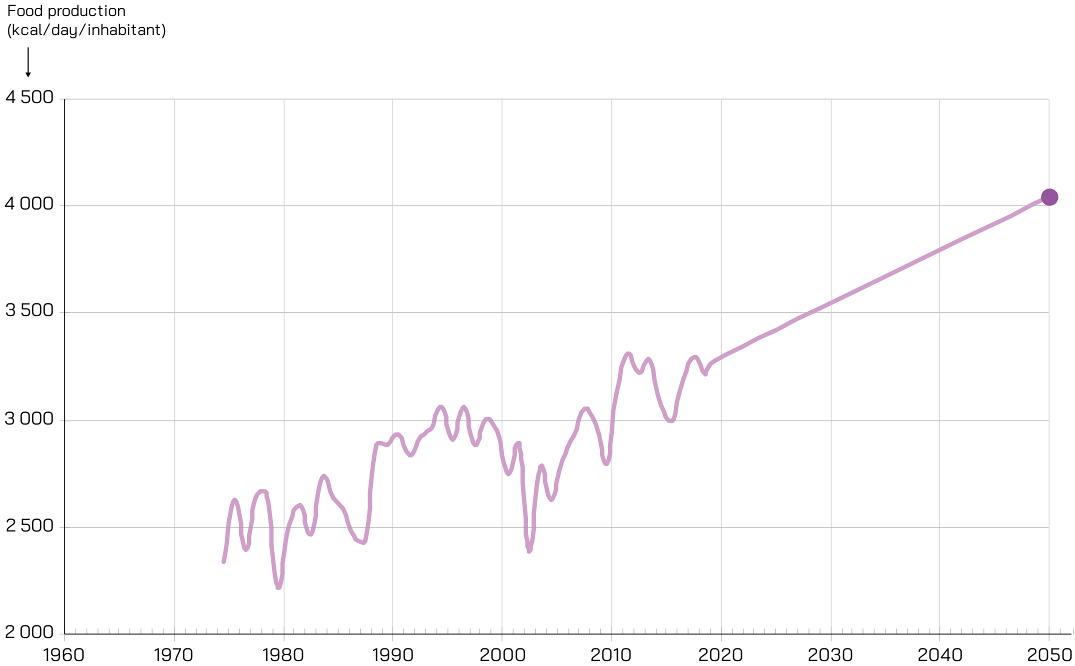


Figure 42

Caloric plant food production per capita in Andhra Pradesh 1973–2050 with the industrial agriculture scenario

Source: Dorin, 2023.

6. Two contrasting paths for the future

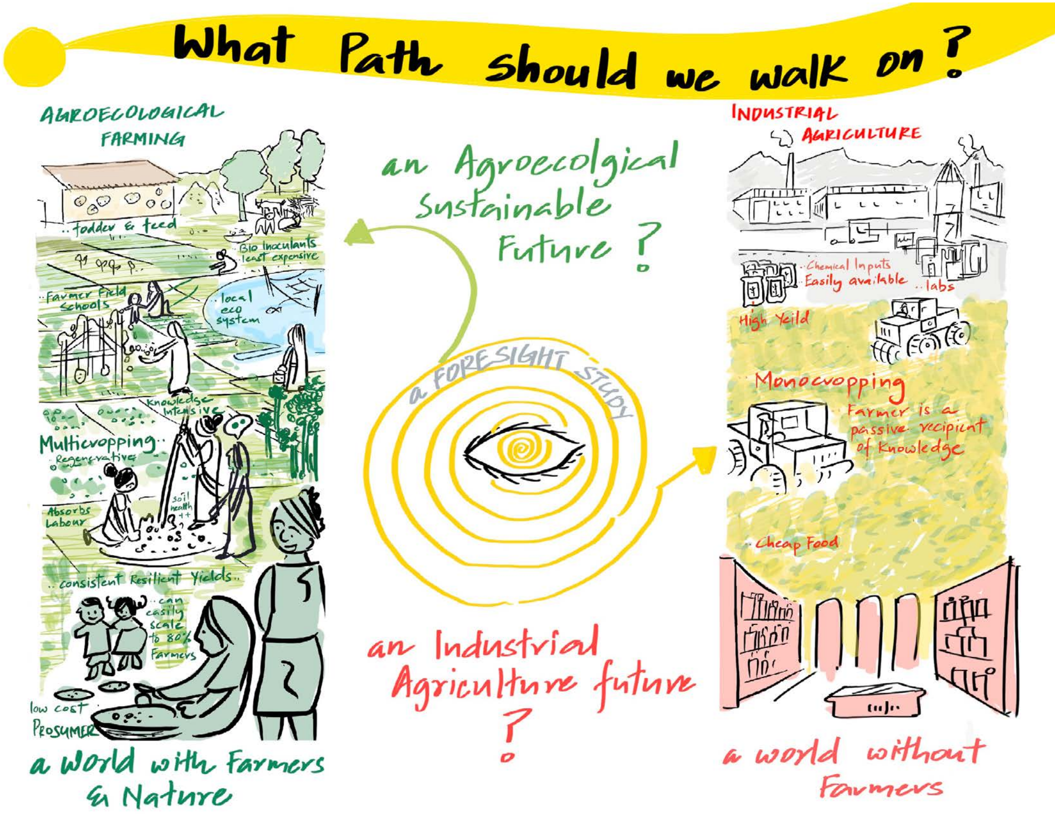


Figure 43

Choosing a path

Source: Srinivas Mangipudi, 2022, New Delhi.

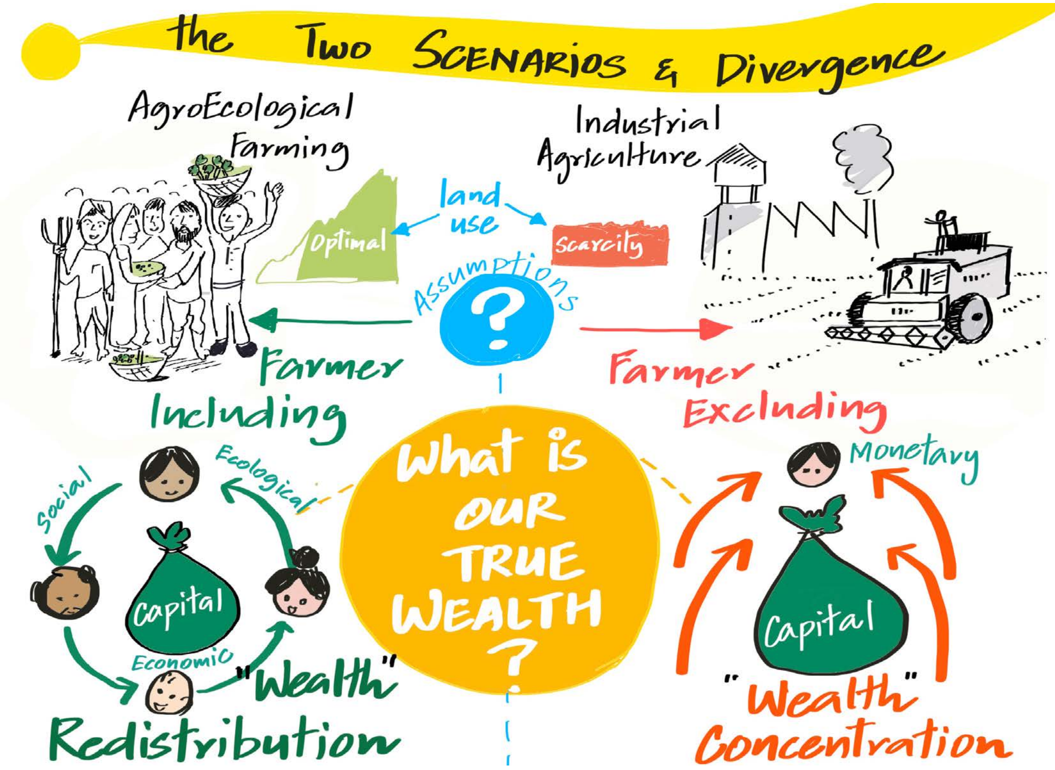


Figure 44

Two scenarios and divergence

Source: Srinivas Mangipudi, 2022, New Delhi

6.1 VISUAL COMPARISON OF QUANTITATIVE ASSUMPTIONS

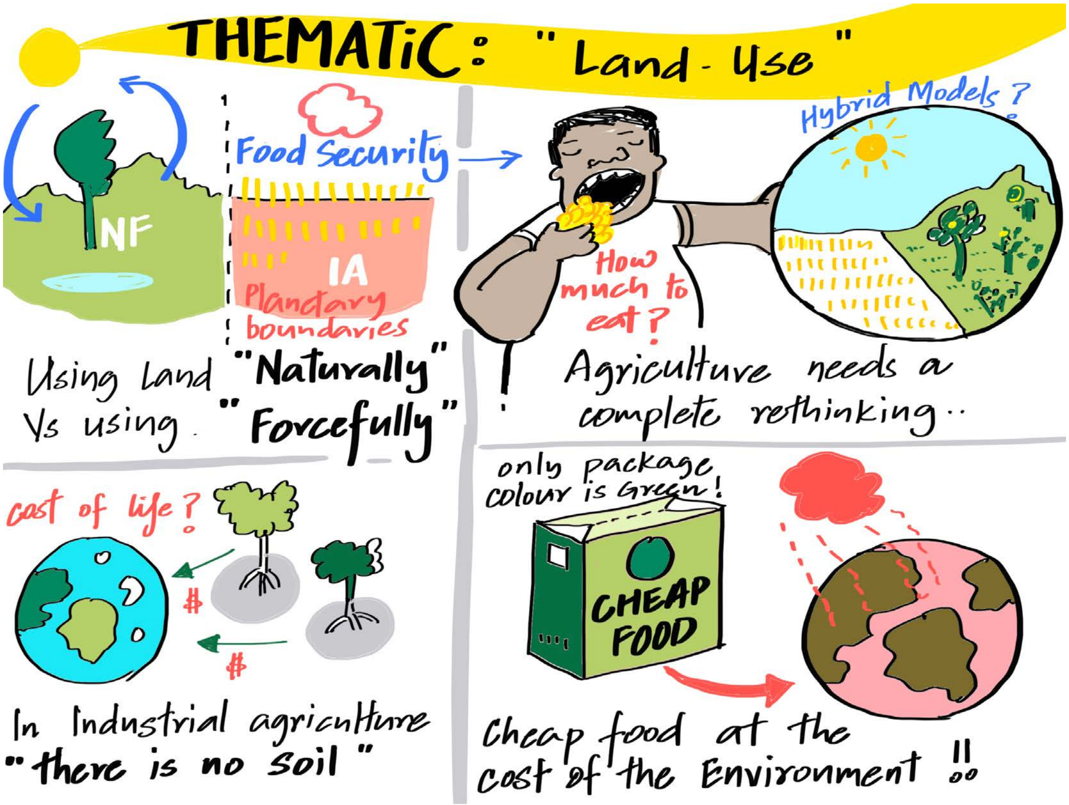
The figures below illustrate and compare the quantitative assumptions used for the two scenarios in the fields of land use (**Figure 46**), population and employment (**Figure 48**), economic growth (**Figure 50**) and caloric food yield per cultivated hectare (**Figure 51**), and compared them with historical values since the 1960s or 1970s. All these figures are preceded by drawings of Srinivas Mangipudi (https://visualthink.in) illustrating the discussions that took place during the AgroEco2050 expert workshop on November 2022 in New Delhi.

6.1.1 Land use

Figure 45

Visions on land use

Source: Srinivas Mangipudi, 2022, New Delhi



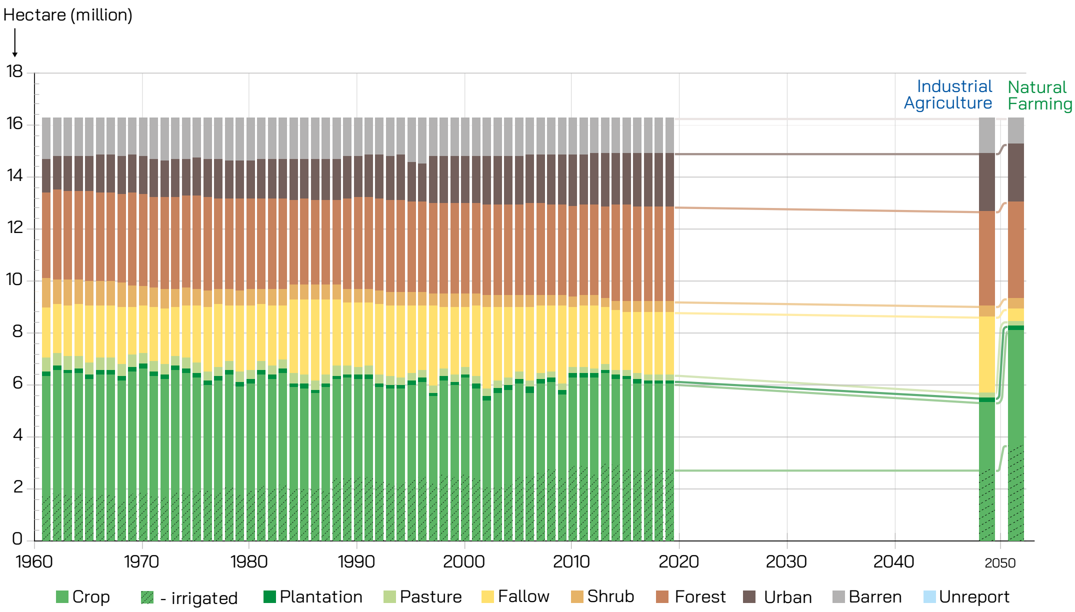


Figure 46

Land use in industrial agriculture and agroecology scenarios, 1961-2050 (hectares)

Source: Dorin, 2023.

6.1.2 Population and employment

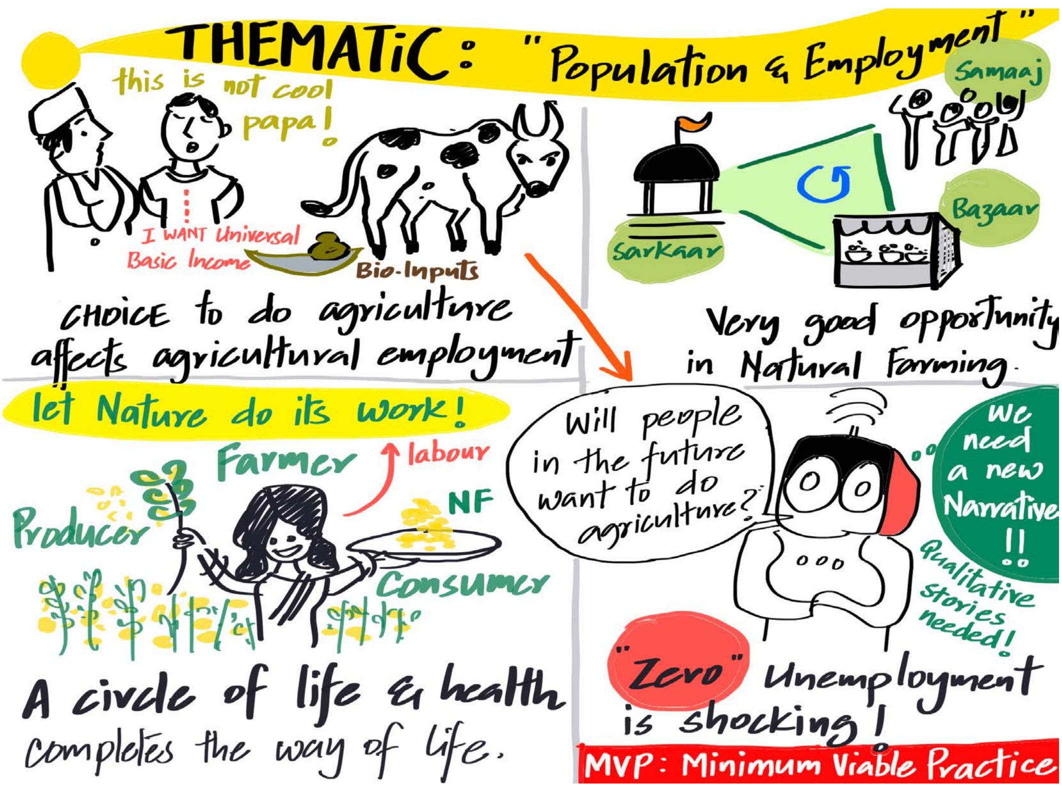


Figure 47

Visions on population and employment

Source: Srinivas Mangipudi, 2022, New Delhi

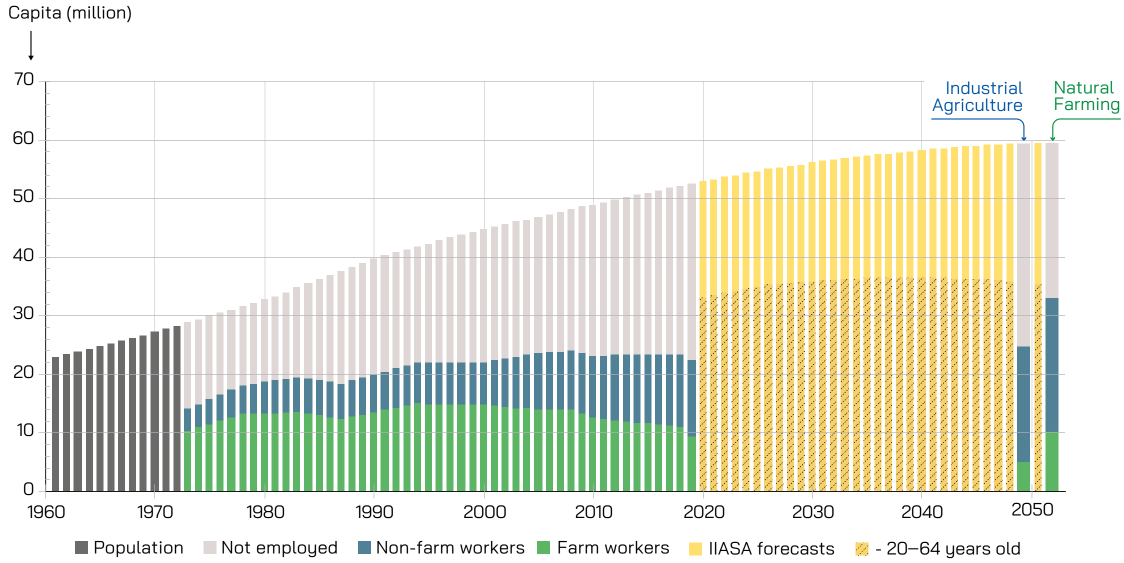


Figure 48

Population and employment in industrial agriculture and agroecology scenarios, 1961–2050

Note: IIASA – International Institute for Applied Systems Analysis (KC et al., 2018)

Source: Dorin, 2023.

6.1.3 Economic growth

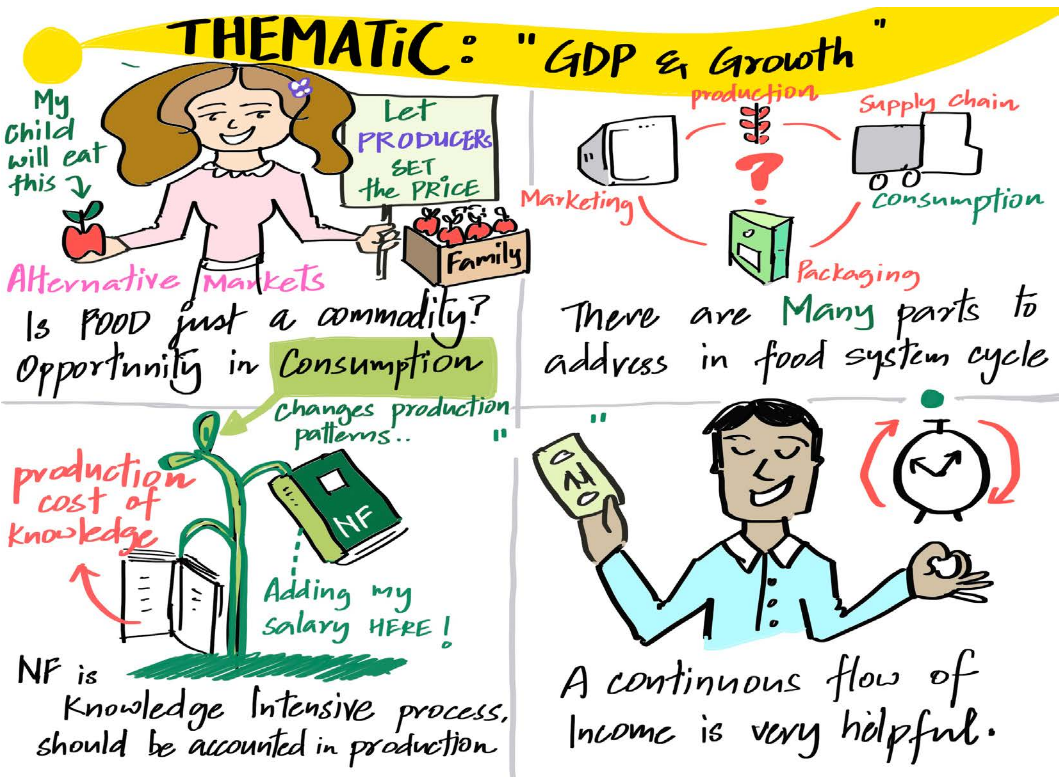


Figure 49

Visions on economic growth

Srinivas Mangipudi, 2022, New Delhi

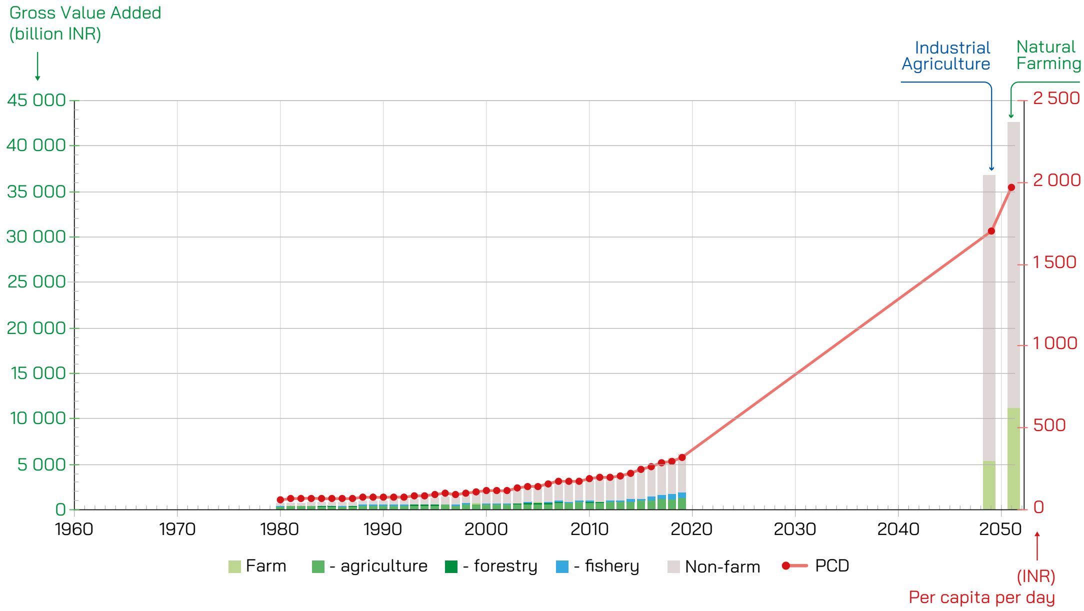


Figure 50

Gross value added in industrial agriculture and agroecology scenarios, 1980–2050

Source: Dorin, 2023.

6.1.4 Food yield and production

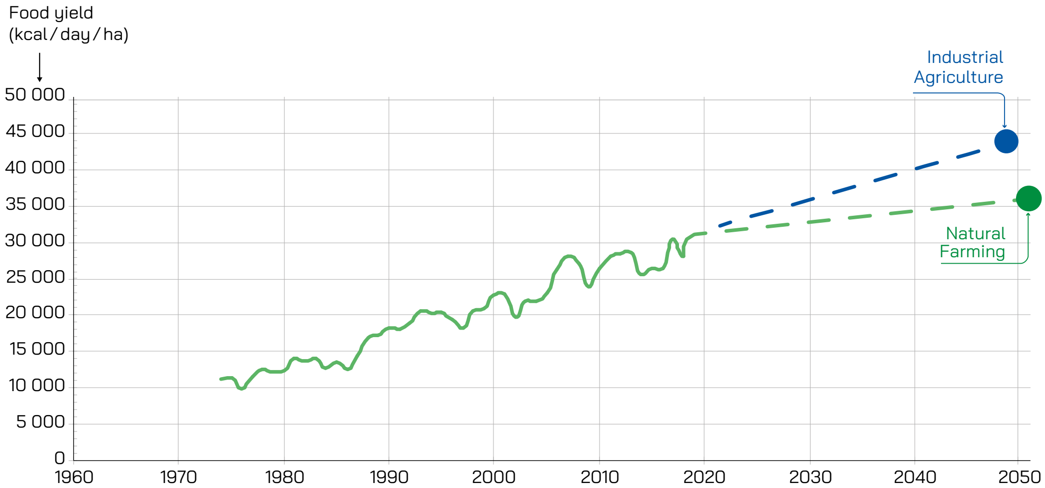


Figure 51

Caloric plant food yield per hectare in industrial agriculture and agroecology scenarios, 1973–2050 (daily kcal/ha)

Source: Dorin, 2023.

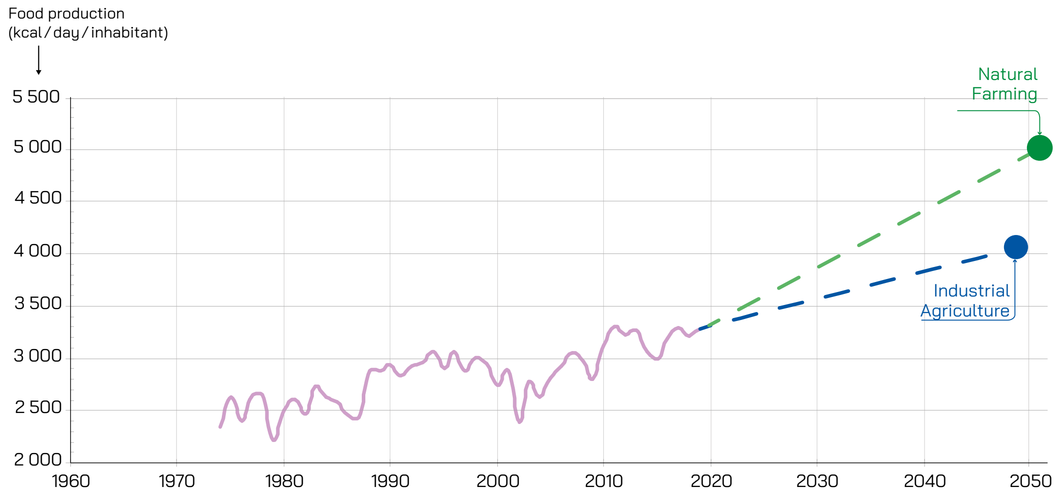


Figure 52

Caloric plant food production per capita in industrial agriculture and agroecology scenarios, 1973–2050

Source: Dorin, 2023.

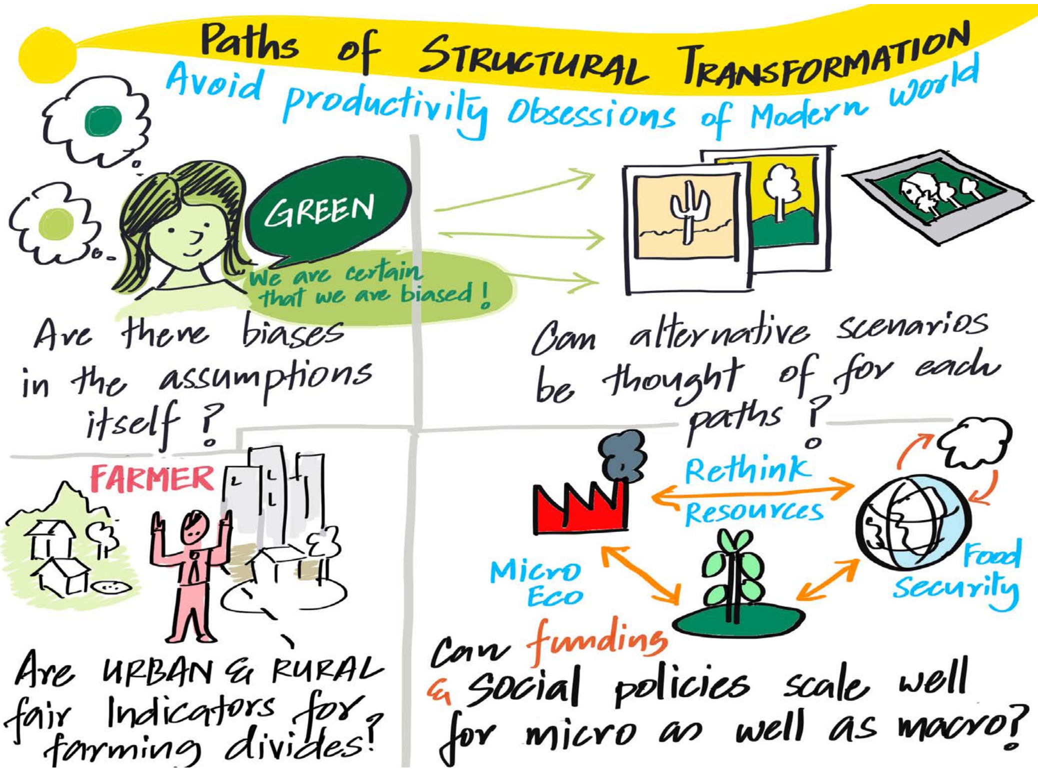
6.2 OUTPUTS FROM THE AGRIBIOM LEWISIAN MODULE

Based on the quantitative assumptions presented previously, the Agribiom Lewisian Module (ALM) computes a set of indicators including their annual growth rates (AGR) over the reference period in the future (here: 2019-2050) to compare them with a period benchmark in the past (here: 1980-2019). **Table 14** and **Table 15** present these results for the IA and NF/AE scenarios.

Figure 53

Questions on structural transformation paths

Source: Srinivas Mangipudi, 2022, New Delhi



Agribiom Lewisian Model (ALM)

Zoning: 02APR | Region: Andhra Pradesh (-TG) | 07/10/2024 at 11:29:43

Param POP — Source: NSS; Status: PS+SS; Sex: All; Zone: All

Param GDP — Gross; Value Added; at Constant; 2011-12; INR; Basic price

		Historical evolution (Agribiom) 1980		2019		AGR 1980-2019 (39 years)	My scenario RySS_IA_10 2019		2050		AGR 2019-2050 (31 years)
Population	Total (cap)	32 800 677		52 568 213		1.22%	52 568 213		59 525 047		0.40%
	- Urban	7 157 962	22%	20 377 108	39%	2.72%	20 377 108	39%	30 400 601	51%	1.30%
	- Density / urbanized ha	22		26		0.43%	26		27		0.16%
Work Force	20-64 years old (cap)			32 543 926	62%		32 543 926	62%	35 349 208	59%	0.27%
	- Unemployed (cap)			10 138 278	31%		10 138 278	31%	10 586 788	30%	0.14%
	Employed (cap)	18 737 979		22 405 648	69%		22 405 648	69%	24 762 420	70%	0.32%
	- Farm	13 356 215	71%	9 300 133	42%	-0.92%	9 300 133	42%	4 952 484	20%	-2.01%
	- Nonfarm	5 381 765	29%	13 105 515	58%	2.31%	13 105 515	58%	19 809 936	80%	1.34%
	Inhab. per farmer (cap)	2.46		5.65		2.16%	5.65		12.02		2.46%
Land	Cultivated (ha)	6 225 900		6 203 180		-0.01%	6 203 180		5 503 000		-0.39%
	Land per farmer (ha)	0.47		0.67		0.92%	0.67		1.11		1.66%
Gross Value Added	Total (million INR)	676 005		6 057 718		5.78%	6 057 718		36 879 998		6.00%
	- Farm	400 875	59%	1 846 267	30%	3.99%	1 846 267	30%	5 363 465	15%	3.50%
	- Nonfarm	275 130	41%	4 211 451	70%	7.25%	4 211 451	70%	31 516 533	85%	6.71%
	GVA/cap/day	56.46		315.71		4.51%	315.71		1697.46		5.58%
Productivity	Labour (INR/day)	98.84		740.73		5.30%	740.73		4080.42		5.66%
	- Farmer	82.23		543.89		4.96%	543.89		2967.08		5.63%
	- Nonfarmer	140.06		880.41		4.83%	880.41		4358.76		5.30%
	Land (INR/ha)	176.41		815.43		4.00%	815.43		2670.26		3.90%
Plant Food Production	Total (Gkcal/day)	77.341		192.885		2.37%	192.885		241.329		0.73%
	- per Hectare (kcal/day)	12 422		31 095		2.38%	31 095		43 854		1.12%
	- per Farmer (kcal/day)	5 791		20 740		3.33%	20 740		48 729		2.79%
	- per Capita (kcal/day)	2 358		3 669		1.14%	3 669		4 054		0.32%
Inequality	Labour Income Ratio (LIR)	0.83		0.73		-0.32%	0.73		0.73		-0.03%
Structural Path						Farmer Excluding					Farmer Excluding

Table 14

AgroEco2050 quantitative scenario for industrial agriculture in Andhra Pradesh

Source: Dorin's Agribiom Lewisan Model.

Agribiom Lewisian Model (ALM)

Zoning: 02APR | Region: Andhra Pradesh (-TG) | 07/10/2024 at 11:29:43

Param POP — Source: NSS; Status: PS+SS; Sex: All; Zone: All

Param GDP — Gross; Value Added; at Constant; 2011-12; INR; Basic price

		Historical evolution (Agribiom) 1980		2019		AGR 1980-2019 (39 years)	My scenario RySS_NF_12 2019		2050		AGR 2019-2050 (31 years)
Population	Total (cap)	32 800 677		52 568 213		1.22%	52 568 213		59 525 047		0.40%
	- Urban	7 157 962	22%	20 377 108	39%	2.72%	20 377 108	39%	30 400 601	51%	1.30%
	- Density / urbanized ha	22		26		0.43%	26		27		0.16%
Work Force	20-64 years old (cap)			32 543 926	62%		32 543 926	62%	35 349 208	59%	0.27%
	- Unemployed (cap)			10 138 278	31%		10 138 278	31%	2 372 223	7%	-4.58%
	Employed (cap)	18 737 979		22 405 648	69%		22 405 648	69%	32 976 985	93%	1.25%
	- Farm	13 356 215	71%	9 300 133	42%	-0.92%	9 300 133	42%	10 000 000	30%	0.23%
	- Nonfarm	5 381 765	29%	13 105 515	58%	2.31%	13 105 515	58%	22 976 985	70%	1.83%
	Inhab. per farmer (cap)	2.46		5.65		2.16%	5.65		5.95		0.17%
Land	Cultivated (ha)	6 225 900		6 203 180		-0.01%	6 203 180		8 280 000		0.94%
	Land per farmer (ha)	0.47		0.67		0.92%	0.67		0.83		0.70%
Gross Value Added	Total (million INR)	676 005		6 057 718		5.78%	6 057 718		42 672 384		6.50%
	- Farm	400 875	59%	1 846 267	30%	3.99%	1 846 267	30%	11 240 262	26%	6.00%
	- Nonfarm	275 130	41%	4 211 451	70%	7.25%	4 211 451	70%	31 432 122	74%	6.70%
	GVA/cap/day	56.46		315.71		4.51%	315.71		1964.06		6.07%
Productivity	Labour (INR/day)	98.84		740.73		5.30%	740.73		3545.22		5.18%
	- Farmer	82.23		543.89		4.96%	543.89		3079.52		5.75%
	- Nonfarmer	140.06		880.41		4.83%	880.41		3747.90		4.78%
	Land (INR/ha)	176.41		815.43		4.00%	815.43		3719.23		5.02%
Plant Food Production	Total (Gkcal/day)	77.341		192.885		2.37%	192.885		298.080		1.41%
	- per Hectare (kcal/day)	12 422		31 095		2.38%	31 095		36 000		0.47%
	- per Farmer (kcal/day)	5 791		20 740		3.33%	20 740		29 808		1.18%
	- per Capita (kcal/day)	2 358		3 669		1.14%	3 669		5 008		1.01%
Inequality	Labour Income Ratio (LIR)	0.83		0.73		-0.32%	0.73		0.87		0.54%
Structural Path						Farmer Excluding					Farmer Developing

Table 15

AgroEco2050 quantitative scenario for agroecology in Andhra Pradesh

Source: Dorin's Agribiom Lewisan Model.

6.3 THE "FARMER EXCLUDING" PATH OF THE INDUSTRIAL SCENARIO

Our two scenarios illustrate two possible but radically different visions of agricultural science and productivity, of societal goals and choices, with their own trade-offs but necessary revolution in one and involution in the other.

The involution of the IA scenario is the intensification, within the Indian context and constraints, of the current dominant regime of industrial agriculture, food and societies. In this IA scenario over 2019-2050, Andhra Pradesh would remain in a **"Farmer Excluding" (FE) path** as during 1980-2019. It is a path **where farmers become fewer and poorer compared to other workers** (for more details on this path, see Table 2). In other words, in this scenario, **farmers almost double their average land availability** (from 0.67 ha in 2019 to 1.11 in 2050) due to their lower number (less than 5 million in 2050 against more than 9 in 2019). This increase in average farm size **would be unprecedented in Indian history** (nearly +1.7 percent per year over 2019–2050), but too low for scale that goes with high levels of mechanization, and hence **does not allow them to narrow their income gap with non-farmers** (mainly due to high production costs and too low economies of scale to amortize them) unlike in most OECD countries where the increase in farm size and their mechanization/robotization (with fossil fuels and other rare resources) has been the main driving force behind the reduction of this income gap (Dorin *et al.*, 2013; Dorin, 2022). The means by which farmers would secure their labour productivity in this scenario remains uncertain, primarily at the lower end of the size even after the augmented average size, due to the potential limitations in accessing the necessary capital and technologies for sustainable land, water and natural resource management techniques, even considering "soilless" agriculture approaches.

To close this gap and break with the agrarian crisis, in this IA scenario:

- Either the number of farmers should have been reduced to nearly 3.6 million instead of almost 5 million in 2050 (*ceteris paribus* or *all other things being equal*), with the assumption that those leaving agriculture would be employed in the non-farm sector and not increase the rate of unemployment or poverty).
- Or the annual growth rate of agricultural value added should be almost three times higher than assumed (i.e. more than 9.5 percent per annum against 3.5 percent), which is unrealistic and inconsistent with this scenario of mass production of low quality cheap products for national and international markets.
- Or income support is granted to farmers. In the latter case, such **income support** would have to represent almost **7 percent of Andhra total GVA in 2050**, through mechanisms adapted to the logic of this scenario: price support (to targeted industrial plant and animal products) and input subsidies (to credit, insurance, power, irrigation, chemicals, genetics, robotization, etc.) as practiced today in India with less intensity (2–2.25% of Indian GDP in the mid-2010s according to Ramaswami, 2019), failed results (high prices and volatility in agricultural commodities, agrarian crisis, farmer suicides, farmer protests) and worrying consequences on many fronts, including human and ecosystem health, and low resilience to climate change.

The way in which this IA scenario would tackle the challenges of declining efficiency in agricultural inputs and diminishing productivity of natural capital while ensuring food security, nutrition, health, and a sustainable development of livelihoods in rural areas would need further consideration. New industrial technologies, which increasingly artificialize the environment such as hydroponics, offer the possibility of producing food with less or even without traditional agricultural land ("soilless" agriculture). While this increased artificialization would further **reduce agricultural area**, as anticipated in this IA scenario (minus 700 000 ha from 2019 to 2050) and may increase areas of greater biodiversity and carbon-rich land such as forests if strictly protected, it would also lead to **higher agricultural production costs** due to the large investments in capital and inputs required for these industrial technologies. Furthermore, the use of these industrial technologies on the best irrigated land would increase the average yield per hectare, as also anticipated in this IA scenario, but with the decrease in cultivated land, this would lead to **no significant increase in food production per capita** as shown in our quantitative exercise (4 055 kcal/cap in 2050 against 3 670 in 2019). Moreover, the nutritional and health quality of this industrial food production can be strongly questioned. All in all, experts caution that food production growth in this scenario may stagnate in the future because of decreasing marginal productivity of industrial inputs and increasing pressure on water, energy, and soil organic matter, in the face of climate change and fossil energy crisis.

Turning now to the need to generate employment and income for the foreseen population growth, it is expected in this IA scenario that **30 percent of the 20 to 64 age group would remain jobless**, representing more than 10.5 million Andhra inhabitants in 2050. It can therefore be expected that the current situation of women in India would continue or worsen, with a very low workforce participation rate. To limit the rise (and costs) of inequality and poverty within the population, a **UBI could be implemented** in this scenario, as is already discussed in low labour-intensive industrial societies, but also in India instead of its existing social welfare (Public Distribution System, Mahatma Gandhi National Rural Employment Guarantee, Mid-day Meal Scheme, etc.) (EPW, 2017b). If this UBI amounted to only 25 percent of the average income of non-farmers, it would then represent more than **11 percent of total Andhra GVA in 2050**. Moreover, the reduction in the number of farmers, and the increase in unemployment, implies a future migration of the impoverished rural population to marginal areas of the cities.

Overall, in this IA scenario, **the cost of such policies to reduce income inequalities and improve social equity would then be at least 18 percent of Andhra total GVA in 2050** (Table 16), which represents more than the GVA share of agriculture in this scenario (15 percent). This is a huge amount. Furthermore this scenario is unlikely to attract significant international green finance in support of this intensive industrial agriculture model; except perhaps through projects similar to the REDD+ or the World Bank Wildlife Conservation Bonds (World Bank, 2022) to finance the carbon or biodiversity restoration or conservation on lands (forests, shrubs, fallows) which this IA scenario would spare from intensive industrial agriculture. As a result, the strategies for inclusive economic growth and rural development in this scenario would entail high levels of private investment, huge public transfer payments and alternative funding mechanisms.

6.4 THE “FARMER DEVELOPING” PATH OF THE AGROECOLOGICAL SCENARIO

The AE scenario illustrates a radically different vision of agricultural science and productivity, of societal goals and choices, and involves a paradigm shift from the current world-dominant sociotechnical regime of industrial production and consumption (Dorin, 2022). In this AE scenario, nature and labour are no longer seen through the prism of few global value chains to be maximized, and in terms of international division of labour to be optimized through economies of scale and robotization. Instead, nature and labour are envisioned as two key resources whose local, complex and synergistic combinations could profit and enhance both. After this transformative activity of self, nature, and the society, Andhra Pradesh would no longer be embarked upon a “Farmer Excluding” (FE) path as during 1980-2019 or in the IA scenario over 2019–2050. It would instead be embarked on a **“Farmer Developing” (FD) path where farm and non-farm labour incomes tend to converge** (i.e. reduced income inequality despite 4.8 percent annual growth in non-farm labour productivity, as during 1980-2019) **while the number of farmers would have increased** (from 9.3 million in 2019 to 10 million in 2050). In the light of population growth and the challenge of youth unemployment, this scenario offers the potential for increased employment and improved incomes for young people in rural areas, while also presenting an opportunity for the "re-employment" of women, aligning with the values of equity and participation that goes along with NF/AE, particularly in response to the trend of women withdrawing from the labour force since 2005.

These rather surprising but mathematical results are based on the Expert Group's assumptions that many people and land will shift to APCNF (almost **8.3 million ha of cultivated area in 2050**, against 6.2 in 2019), as a result of **lower costs of production** (seeds, irrigation, chemicals, credit, insurance, robots, etc.), the **regeneration of degraded lands**, greater care and **more efficient use of water, high yields of useful biomasses on the same plot of land, better valuation on markets** (chemical-free products, etc.), the aesthetic value of the **diversified landscapes,** as well as the **happiness in cultivating nature** and in **valorizing locally and collectively** the tremendous productivity potential of **cultural, social and health values**, instead of mining them through costly top-down industrial technology. All this together would lead to an **unprecedented growth rate in agricultural GVA** (**6 percent** per annum over 2019–2050 against 4 percent over 1980–2019), and **despite the high number of farmers** (10 million against less than 5 in the IA scenario), it would also lead to **higher labour productivity growth** for farmers (5.8 percent per annum over 2019–2050) than for non-farmers (4.8 percent), hence **reduce the farm–non-farm labour productivity gap**. Reducing capital requirements and dependence on external inputs would benefit **women** farmers, who often have lower incomes and little access to credit and subsidies. Similarly, despite **0.8 ha of cultivated land per farmer** on average (0.7 ha in 2019 and more than 1.1 ha in the IA scenario), it would also lead to higher land incomes in 2050 than in the IA scenario (INR 3 720 against 2 670 in 2011–12 rupees per hectare per day). All in all, in 2050, the **average NF/AE farmer would earn as much as the average IA farmer, i.e. about INR 3 000 of GVA per day**, and even a bit more (INR 3 080 INR/day against 2 970).

As far as the **farm–non-farm income gap** is concerned (difference in average incomes between farmers and non-farmers), it would **have narrowed but not disappeared** in this AE scenario. This 2050 gap would be less than in 2019 (22 percent against 62 percent) and less than in the IA scenario (22 percent against 47 percent), but would still represent **one-fifth of the average farmers' income in 2050**.

To close the gap in this AE scenario:

- either the number of farmers should remain the same as in 2019 (i.e. 9.3 million);
- or the annual growth rate of agricultural value added should increase to more than 10 percent per annum, which is quite unrealistic even if production costs were drastically reduced in natural farming, and even if agricultural production is very highly valued;
- or farmers should obtain additional income through mechanisms adapted to the logic of this scenario.

This logic is not the one of capital/energy/land-intensive agriculture for very few farmers (as in the IA scenario and even more in OECD countries), but the one of **agroecology with many farmers** whose production of food and environmental services is all the more efficient since they operate at small scale. This **micro-operating scale is a condition for efficiency** (high yield and environmental services with low inputs), **but also a ceiling for income** that needs public support to enable sustainable livelihoods as much as due considerations of equity.

So agroecological farmers could also be remunerated for the environmental services they provide (currently unpaid) to close the remaining income inequality between farmers and non-farmers. With Natural Farming, thanks to highly biodiverse agroecosystems, **environmental services** to local and global societies would be numerous, such as **water saving and filtering, storage of soil organic carbon and mitigation of climate change, resilience to biotic and abiotic shocks.** Payments for environmental services (PES) could be granted to each farmer (whether cultivator or labourer) after evaluating and monitoring the extent to which their village or region practices multi–service agroecology. In our AE scenario, to close the farmer–non-farmer income gap, these **PES would represent 6 percent of the total Andhra GVA** of 2050. Additionally, the greater resilience of the NF model could reduce agricultural risk, ensuring greater security, stability and predictability for farmers and agricultural stakeholders in the face of economic and ecological changes.

After closing the farm–non-farm income gap through PES in this NF/AE scenario, we should add, as in the IA scenario, a kind of **UBI** to narrow the income gap between employed and non-employed people. With the same assumptions (UBI at 25 percent of the average income of non-farmers), it would then represent less than **2 percent of total Andhra GVA** in 2050, i.e. much less than in the IA scenario (more than 11 percent) since we have only 7 percent of the 20 to 64 age group remaining unemployed in this NF/AE scenario (against 30 percent in the IA scenario).

In this NF/AE scenario, **the cost of policies to reduce income inequalities would then be much lower than in the IA scenario, i.e. less than 8 percent against more than 18 percent of Andhra GVA in 2050** (Table 16). This NF/AE scenario would also have the huge advantage of boosting environmental services, of being resilient to climate change and energy prices, of reducing the burden and cost of pesticides and chemical fertilizers on human and ecosystem health. Moreover, prospects of obtaining international funds to finance this policy would be much higher than in the other scenario, in particular to help store large quantities of carbon and biodiversity through agricultural lands and efficient agroecology practiced on a small scale by millions of farmers, with great opportunities for inclusive economic growth and social equity.

Last but not least, we show that the total **food production** of 2050 expressed in kilocalories per inhabitant would be significantly **higher in this AE scenario** than in the IA scenario (5 000 kcal/capita/day against 4 050, and 3 660 in 2019). This AE food production would also be much more balanced and healthier than today.

Overall, compared to the current techno-centric and capital-intensive industrial agriculture and food, this AE scenario suggests an alternative that would be:

- **more productive in terms of useful biomass per inhabitant** (from multiple crops/tree/animals on the same area of land);
- **more resilient** to economic, climate and biotic shocks;
- **more labour** intensive than capital intensive, thus supporting the livelihoods of small farmers and landless labourers;
- **more profitable for farmers,** especially **women**, if input costs are cut, and if diverse, tasty, nutritious and healthy foods are better priced on local and international markets, along with remuneration for the production of environmental goods or services (currently unpaid) that are of local or global value, such as drinking water, biodiversity reservoirs, soil fertility, nutrient recycling, pollination, combatting diseases or floods, mitigation of, and adaptation to climate change, prevention of obesity and non-communicable diseases, etc.

The NF/AE scenario would thus transform the state's agricultural landscape, ushering in a new era of regenerative agriculture and bountiful harvests. Vibrant and diverse agroecosystems would flourish across the state. Lush green landscapes would showcase intercropped fields teeming with a plethora of crops – from traditional grains and legumes to exotic fruits and vegetables. Natural farming techniques would have invigorated the soil, resulting in nutrient-rich, living soils that thrive with beneficial microbes and earthworms. The transformational shift in cropping patterns would enable farmers to adopt multi-layered agroforestry systems. Former fallow and barren lands would host a mosaic of fruit-bearing trees, nitrogen-fixing shrubs, and medicinal plants. Farmers would discover the symbiotic relationships between crops and trees, unlocking the potential of integrated farming systems that are not only sustainable but also economically rewarding.

Table 16. Cost of policies to reduce income inequality in the industrial agriculture and agroecology scenarios for 2050 (million INR-2011)

	IA scenario	NF/AE scenario
(1) Policy to close the farm–non-farm income gap		
- Input and price subsidies	2 515 668	
- Payments for environmental services		2 439 567
(2) Policy to reduce inequality with jobless people - UBI at 25% of non-farm income	4 210 751	811 290
(3) Total costs	6 726 420	3 250 857
(4) Total GVA	36 879 998	42 672 384
(5) Costs/GVA (%)	18.2	7.6

Note: UBI – universal basic income; GVA – gross value added; IA – industrial agriculture; NF – natural farming; AE – agroecology. Source: Dorin, 2023

7. General conclusion

7.1 A LEARNING JOURNEY

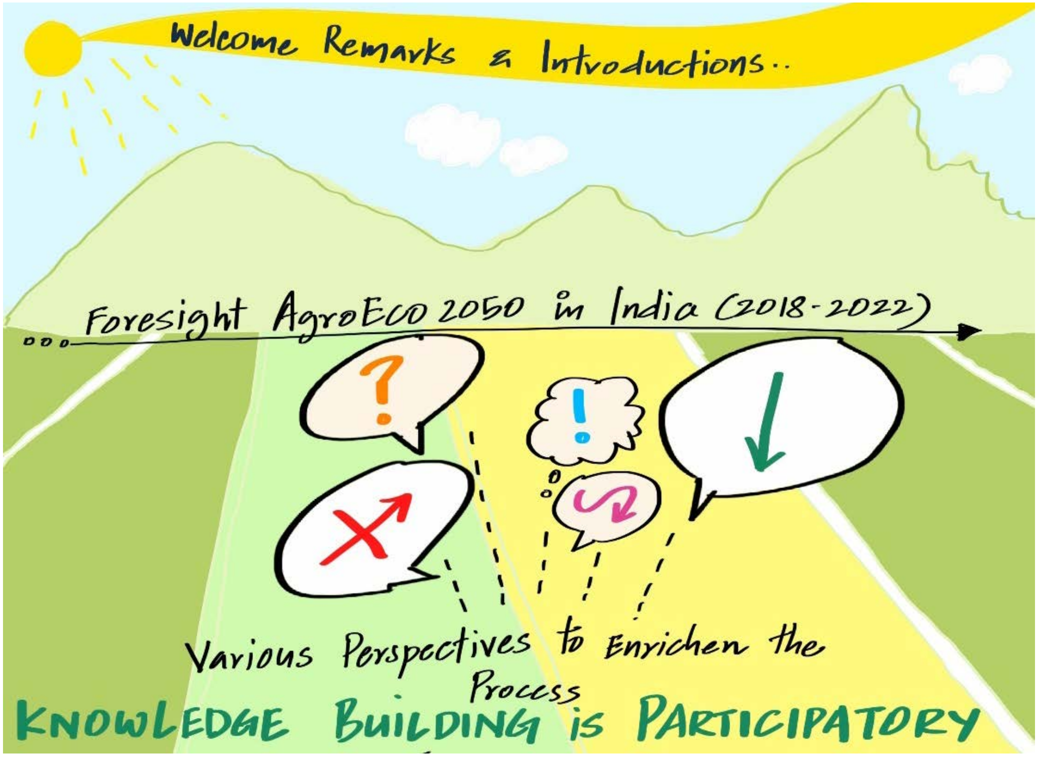


Figure 54

Foresight AgroEco2050 in India

Source: Srinivas Mangipudi, 2022, New Delhi

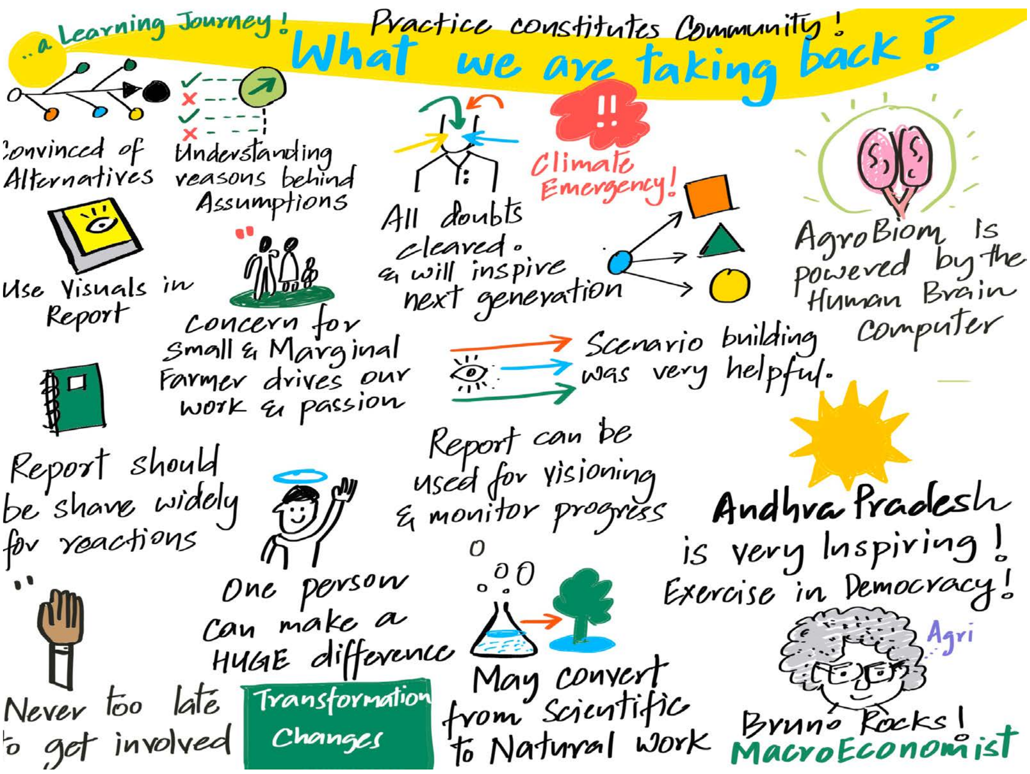


Figure 55

What we are taking back?

Source: Srinivas Mangipudi, 2022, New Delhi

The AgroEco2050 foresight process summarized in this study was conducted through extensive methodological and writing work from late 2018 to 2023, by a Project Team from RySS (Government of Andhra Pradesh), CIRAD/CIRED, and FAO (FAO Plant Production and Protection Division and FAO India). It was based on the collective expertise and vision of a multistakeholder Expert Group that worked together in India from 2020 to 2022, as well as a numeric tool, "Agribiom-India" (B. Dorin, CIRAD), developed and customized for this collective foresight exercise. The model Agribiom-India and its interface were used interactively by the group to scan and better understand past structural transformations from the 1960s to 2019-20 (in terms of land use, population, employment, sectoral economic growth, productivity), then to test the coherence and adjust the assumptions made for two contrasting scenarios in 2050. As theorized by Dorin and Joly (2020), the process was anchored in a vision of modelling not as a "black box" where many scenario variables and parameters are set by few academics and their own world views, but as a "learning machine" (not to be confused with "machine learning"!) supporting an iterative and creative work by a diverse collective of stakeholders with their own knowledge and visions, ultimately ambitioning to constitute an exercise in participative democracy.

As can be imagined, this process was in fact a significant "learning journey" for both the Project Team and Expert Group members. Some of the methodological challenges and lessons learnt are summarized hereafter.

On the novel contributions of the study: the book brings some important and unique contributions, in particular:

- A unique compendium of consistent annual statistics
  - over more than half a century (from the 1960s to 2020);
  - at three geographical scales: World, India and Andhra Pradesh;
  - on the multiple and interconnected dimensions of the agrifood systems: land use, population and employment, GDP and sectoral gross value added, land and labour productivities, farm–non-farm income gap, food yield and production in calories, etc.
- The first quantified macroeconomic scenario of a full transition to agroecology by 2050 for a State of 53 million people in southern India, and its comparison with an intensification-scenario of industrial food and agriculture.
- A unique presentation of the method and results of a "participatory foresight" which combines quantitative and qualitative expertise, knowledge and approaches to help societies and their decision-makers to better choose the future world in which they would like to live and work.

This is the fruit of extensive work over several years, combining quantitative and qualitative participatory approaches, and it is thanks to the dedicated contributions of a rich and diverse group of stakeholders from India and beyond, in ways that are further outlined in this section.

On Expert Group formation: It is generally challenging to manage a group of over 30–40 participants for a participatory and creative exercise; this reality therefore limited the number of experts who could be invited to become members of the Expert Group, which in the end totalled about 40 participants. This constitutes one limit of the methodology, as the need for a setting conducive to active participation over a long period restricts the number of people who can be directly involved, and therefore have a direct say in influencing the vision and process. However, the foresight results can later be debated in multiple fora (local, national and international), as was the case with Agrimonde (Paillard *et al.*, 2014) which was presented and discussed in various places in France (ministries, scientific academies, universities and schools, research centres, non-governmental organizations (NGOs), national and local assemblies, etc.) and abroad (FAO, World Bank, OECD, etc.) next to many articles in the press. This is the process which now lies ahead for the Project Team and Expert Group in coming months and years: presenting and debating the results with broader stakeholder groups and policymakers in India and abroad.

During the formation of the Expert Group in late 2019, it also proved complex to equally attract experts from all stakeholder groups. Limiting factors may have included: the expected length of the exercise and significant time commitment required (initially announced as four in-person workshops of four days each); the methodologically-complex nature of the interdisciplinary exercise; or the inherent prerequisite of being interested in debating the merits of agroecology and natural farming in India, a rather controversial argument when the study process started. As a result, there were relatively fewer participants from farmer organizations and none from agroindustry, and more academic, NGO and development experts. Similarly, most experts who proved willing to join the expert group were either favourably disposed towards agroecology or sceptical but curious and open to learn about the issue, whereas it proved more difficult to attract participants who strongly promote industrial food and agriculture, and were staunchly opposed to agroecology. Experts nonetheless did their best to do justice to the various viewpoints crystallizing in the two scenarios. They sought to consider all sides of each argument, and role playing was employed at times to capture any viewpoints opposed to one's own. However, this composition of the working group needs to be noted.

On Expert Group participation: continuity in participation till the conclusion of the study was a prerequisite condition to become an Expert Group member. In practice, and despite good intentions and best efforts from almost every participant, there was some lack of continuity in participation by members in workshops. Besides a core group from the Project Team in the three organization institutions (CIRAD, RySS and FAO), most experts did not manage to attend all seven virtual workshops and the two in-person workshops. This required a very iterative process to update those experts who did not attend the previous workshop and, sometimes, to renegotiate the conclusions that had been reached in previous meetings. This unavoidable reality when working with a large and diverse group has to be factored in the design and timeline of future similar exercises.

On the timeline of the process: the entire process of conducting the foresight exercise also took longer than expected, from the preparatory work (end of 2018) and the first small meeting presenting the methodology to AP policymakers (May 2019), to the final report being finalized in the second half of 2023. The COVID-19 emergency disrupted the process, delaying the creation of the Expert Group and hindering in-presence workshops, forcing the Project Team to conduct seven virtual workshops of a few hours each during the COVID-19 emergency, followed by only two in-person workshops (in Anantapur in September 2021 and in Delhi in November 2022) rather than the anticipated four in-person workshops of four-day each which were initially planned. Also, a parallel exercise of visioning and scenario building with and by communities practicing natural farming and industrial agriculture was envisaged in the early stages; but this critical idea had to be quickly put aside due to the COVID-19 emergency. By the time physical meetings were possible again, the relocation of both the FAO and CIRAD project leads to Europe also hindered their travel to India in the COVID-19 context.

On Expert Group dialogues: the diversity in life experience and background of participants undoubtedly made the richness of this foresight exercise. Due to their diverse backgrounds, personal histories or disciplines, participants were also unevenly equipped to juggle with macroeconomic concepts, elaborations on millions of quantitative data, or dense series of complex graphs. The understanding of the differences between foresight (based on visions and rationalities of this or that possible world) and forecasting (of what is most likely to happen) also took time to be assimilated. The scenario building took multiple iterations, with each layer of workshops helping to clarify and unveil new understandings. It was often overwhelming, and always intellectually intense. However, this made for a very rich confrontation of viewpoints and concepts. The contributions of participants elicited and captured in various forms (open discussions, presentations, open questioning, testing and revision of quantified hypothesis in real time through the Agribiom interface, videos, drawings, role plays, "travelling workshop" through joint field visits...), were all valued and recorded, and came to form part of the broader vision for the study. During the last in-person workshop in Delhi in November 2022, the debates and revisions of scenarios were captured in real time through drawings by Visual Think, which were presented to participants at regular intervals during the workshop. This visual representation of debates was felt to be a great addition to the thinking and visioning process; participants felt that this immediate mirroring and the visual shortcuts or representations of the discussions greatly contributed to opening the imagination and at the same time generated debate and critical thinking, which further fed scenario building.

Ultimately, the macroeconomic framing and vision chosen at the beginning of the process however remained the prevalent language for the study and the basis for final arbitration in scenario building. A key lesson learned is, for sure, the need to give time to the foresight process, and to invest in "translating" knowledge and statistics and concepts into language, realities, narratives and visual support that can be understood by all. Context permitting (noting that in our case, the process was heavily disrupted by the COVID-19 emergency, thus limiting the space for methodological creativity), the use of complementary methodologies (drawings, role playing, community-level brainstorming and focus groups, visioning exercise with farmers, etc.) should be intensified in similar future exercises.

All in all, despite some positive aspects of virtual workshops (in terms of cost and carbon-miles savings), the Project Team felt that such foresight processes are best conducted through in-person workshops as was initially envisaged, as they are most conducive to visioning exercises, creativity, in depth confrontation of viewpoints and scenario building.

On the quantified dimensions of the study: dimensions that the foresight study was initially hoping to address, could not ultimately be covered, in particular on human and animal diets, trade and overall supply-utilization accounts in calories and macronutrients. This was because of the COVID-19 emergency that disrupted the work processes planned, as well as the lack of statistics (such as food and feed trade between the Indian states, or detailed state-wise food and non-food use of plant and animal biomass). Furthermore, there were delays in obtaining consistent and updated Indian data over the past decades, which would have helped form the basis for deducting past missing estimates or modelling a framework for the future, especially for animal feed. Nonetheless, significant time was devoted to compiling or estimating annual numerical series, such as: animal populations by species, gender, age and function with livestock quinquennial censuses from 1966 to 2019; greenhouse gas emissions from crops and livestock; the virtual consumption of energy and water by crops; the volumes of subsidies for agricultural inputs (fertilizer, electricity, credit, etc.) and price support for a few products (wheat, rice, sugarcane, etc.). But the work could not be completed because of the lack of time, or technical difficulties. These issues do not detract from the robustness of the findings, which are based on unheard-of statistical series, but they comprise areas for further study and investigation moving forward.

On merging quantitative and qualitative approaches: the study methodology relied on experts revisiting past trends and current data on the agrifood economy in Andhra Pradesh and other Indian states, envisioning future scenarios for Andhra Pradesh and checking their internal coherence using the statistical and modelling interface of Agribiom-India designed for this purpose. The creative work of scenario-building thus required to capture ideas from expert group members through a qualitative process, which had to be documented by taking detailed notes. This was a challenging process, even within the project team that had to convey and attribute proper importance and scientific value to capturing in detail the expert judgments and assessments as the key resource to build scenarios.

On ground-truthing to inspire imagination: the development of the natural farming (agroecological) scenario was not accomplished abstractly, but was directly anchored in the daily realities and real-life impacts of the APCNF programme. There were several presentations of impacts and current data, and one leg of the Anantapur workshop of September 2021 was accomplished with a "travelling workshop", through which the Expert Group members visited farms together, and were able to converse with APCNF farmers. This clearly sustained and carried participants into our conception of the Agroecology scenario, causing it to be more grounded and realistic, alongside a growing body of evidence from independent studies on APCNF.

On participants' learning: at the conclusion of the Study Validation Workshop in Delhi in December 2022, participants took time to reflect on their experiences with this foresight process. They were unanimous that the foresight exercise enormously enriched their experience and knowledge, learning from people with diverse backgrounds and opinions. The process provided new perspectives on arguments and counterarguments, and in the words of one participant, it was valuable precisely because it helped to "acknowledge the debate and heterogeneity, but not necessarily to resolve them".

The best part was felt to be the scenario-building using macroeconomic variables. Many expressed that the scenario-building and the quantification process through the Agribiom model and its interface particularly helped them convert realities and visions into numbers, and test and revise their assumptions. The study process also introduced and created space for discussion of new estimates that were related to caloric food production and yield; public support to agriculture; the reduction of income inequalities; and environmental services.

Only a small fraction of Agribiom-India's extraordinarily rich data and modelling was used during the workshops, but the version of the model allowed for rich open discussions between academics and practitioners, and undoubtedly, enabled the participants to clarify and quantify the most important dimensions of each scenario. All in all, the Agribiom interface helped participants apply foresight tools and methods for innovative research to prioritize development, to further assist them in strategic planning and policy formulation for the relevant transformation of agriculture and food systems.

In the words of one participant, the "human brain computer is powering Agribiom; we had the model and data, but human brains drove the whole effort". This is precisely the purpose and ambition of Agribiom. Many participants were amazed by the statistical details and robustness, and by the zeal and dedication that was put into the process, some described it as "extraordinary".

Expert Group members who were already engaged in agroecological initiatives felt that the process deepened their understanding, and further supported their advocacy efforts by providing robust quantified scenarios. Other participants, who had initially come to the process feeling sceptical, felt that it had been a very helpful journey providing them with a more complete understanding of agroecology and its potential, and of the implications and the hidden assumptions behind the different pathways. A few participants explained that this process convinced them to remain open and to keep exploring and, in the words of one participant, to "give a chance to natural farming".

On the changing context about Natural Farming: this individual evolution process of experts through the life of the study mirrored – but to some extent contributed to – a gradual (and clearly still ongoing) process of increased acceptability of exploring Natural Farming in the Indian Government and policymaking. Key government stakeholders and the Indian Council for Agricultural Research (ICAR) have taken a more positive stance on natural farming than when the study initially started, and some supportive decisions have been taken by the Government of India and several States (for instance: to include natural farming in university curricula, or to develop State-level natural farming programmes). Natural Farming has also gained back-up from the policy leadership in Andhra Pradesh. Luckily, maybe, this may cause the book to become, to some extent, not as "burningly useful" than as when the process started, while the book remains extremely helpful for backing policy and investment discussions with decision-makers.

On moving from Andhra Pradesh to the global level: at the Delhi Validation Workshop in November 2022, participants were asked not to hold on to the power of this foresight model, and to use it to answer more questions in a later version of the study in a few years. Beyond Andhra Pradesh, this project has charted new ground at the national and global level as it has brought about the above-mentioned important methodological contributions. Further, globally there is limited literature on the challenging issue of the macroeconomic implications of agroecological transitions. Macroeconomic dimensions and implications of agroecology, including employment, GDP or income inequality, are generally under-researched and understood in the global literature and discussions, as they are currently focused on dimensions such as yields, environmental impacts or farm level income.

For FAO, this project led to a deepened understanding of the use and potential of foresight tools. The foresight exercise in Andhra is one of the trailblazers in modelling agroecology in foresight scenarios. It has opened broader interrogations and led FAO and CIRAD to review the integration of agroecological options in recent food and agriculture scenarios at the global level. A new project on this has begun with support from the German Government through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (English: German Corporation for International Cooperation) at the end of 2021, in collaboration with CIRAD. This had led to international consultations, a global workshop, organized by FAO, CIRAD and GIZ, to discuss "Foresight and Agroecology" in Rome in November 2022, and a new foresight exercise in Senegal, which was inspired by the present foresight study after the development of "Agribiom-Senegal". This has led to including agroecological options in foresight exercises, which are now on the agenda of international specialized fora, such as part of the Foresight for Food Platform, which gathers global experts of foresight in food and agriculture, or the Transformative Partnership Platform on agroecology.

The contribution of all members of the Expert Groups, and beyond, the inspiration of women and men farmers and field staff of the APCNF programmes, are gratefully acknowledged in sparking this international interest and debate, hopefully leading to opening diverse visions and options for our collective futures in the face of burning global challenges.

7.2 BACK TO THE FUTURE

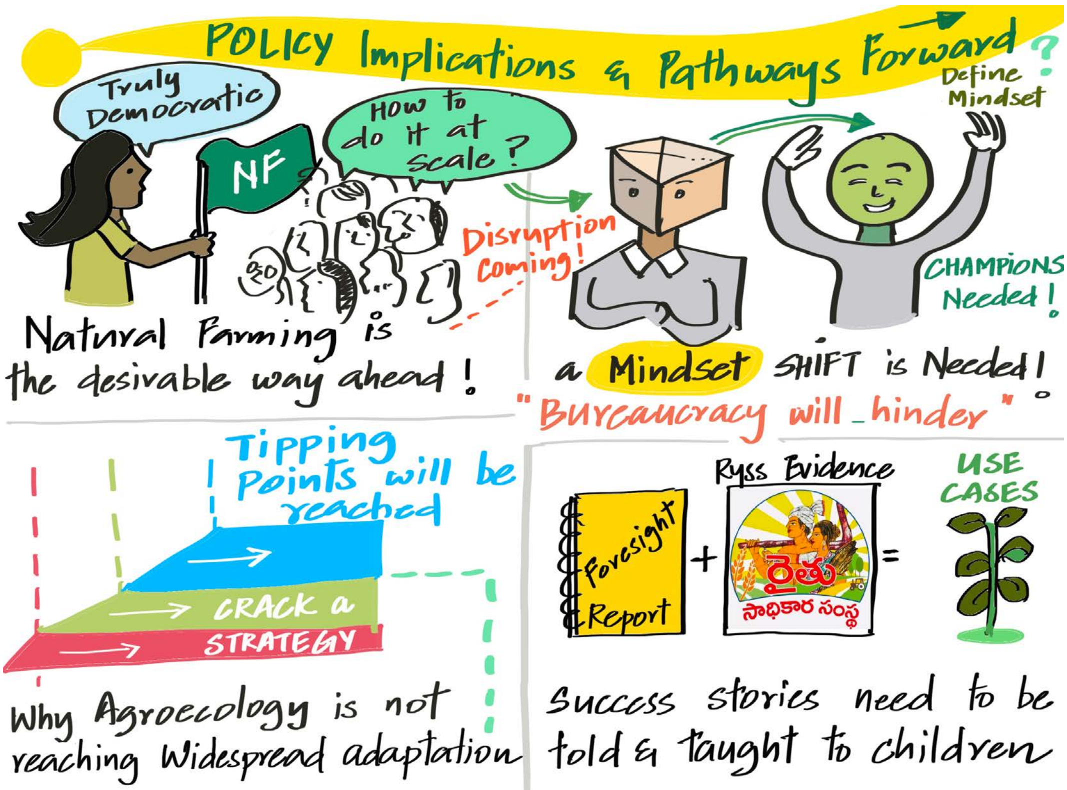


Figure 56

Policy implications and pathways?

Source: Srinivas Mangipudi, 2022, New Delhi

In India, agrifood systems face increasing pressure to meet nutrition, health, employment and poverty eradication targets while addressing environmental degradation and climate change impacts. The findings of our study emphasize the pressing need for holistic and integrated approaches to address such systemic challenges.

Our study **had three main objectives:**

- to provide an image of what a complete transition of Andhra Pradesh to agroecology could look like, especially to better understand the conditions of such a transformation;
- to compare this ideal type of transformation with that of industrial agriculture (IA) which has guided public policies, industries, agricultural production and food since the 1960s in India (and elsewhere);
- to contribute to national and international debates and research on the future of food and agriculture including agroecology, with the overall aim of transitioning towards sustainable food systems leaving no one behind.

In the **NF/AE scenario**, a dynamic transition towards agroecology unfolds, paving the way for a holistic approach to agricultural practices. A staggering 93 percent of 20 to 64 year-old adults find employment, with 10 million individuals (which would represent 30 percent of the workforce) engaged in agriculture and allied activities, marking a reversal of the decline in the agricultural workforce. Embracing the Andhra Pradesh Community-managed Natural Farming philosophy and practices, these farmers regenerate degraded soils and ecosystems, nurturing complex multi-crop-livestock landscapes that are characterized by rich soil microbiomes and thriving trees. This concerted effort enables cultivation expansion of 2 million ha, without encroaching on existing forest or shrub areas. By 2050, Andhra Pradesh would boast over 8 million ha of cultivated land, setting the stage for a thriving agricultural sector.

With low-input but high-output practices, the AE scenario propels a robust 6 percent annual growth in agriculture GVA, a stark contrast to the 4 percent witnessed in the previous decades under IA. This growth reflects a larger vision for an all-sector economic expansion of 6.5 percent per annum, fuelled by a full-employment landscape predominantly based on agriculture and allied activities. As farmers earn approximately 5.5 times more income than in 2019, they witness their hard work yielding a daily income of about INR 3 000, which has fostered a sense of security and prosperity among farming communities.

In this scenario, nature and labour are envisioned as two key resources whose local, complex and synergistic combinations could profit and enhance both, underpinned by a strong commitment to inclusivity. In this line, Andhra Pradesh would embark on a "Farmer Developing" (FD) path where farm and non-farm labour incomes tend to converge (i.e. reduced income inequality despite 4.8 percent annual growth in non-farm labour productivity, as was the case during 1980–2019) while the number of farmers would have increased (from 9.3 million in 2019 to 10 million in 2050). In light of population growth and the challenge of youth unemployment, this scenario offers the potential for increased employment and improved incomes for young people in rural areas, while also presenting an opportunity for the "re-employment" of women, particularly in response to the trend of women withdrawing from the workforce since 2005. The vision embraces the notion that agriculture operates most efficiently and productively on small scales, ensuring a stable supply of nutrient-rich foods. This regenerative approach fosters social equity and environmental stewardship, resonating with the SDGs. This scenario also encompasses additional benefits linked to the aesthetic and recreational value of the diversified landscapes as well as the happiness and dignity of farmers in cultivating nature and in valorizing locally and collectively the tremendous productivity potential of cultural and social values. It foresees people who are closely connected to the natural environment, and an increased number of farmers as protagonists and stewards of natural resources governance, resulting in positive impacts on ecosystem and human health.

In stark contrast, **the IA scenario** unfolds with a vision that intensifies the existing capital-intensive and techno-centric industrial agriculture paradigm. Unemployment among the 20 to 64 year-olds would remain at the disturbing level of 30 percent in 2019. Indeed, in this scenario, the automation of human activities and energy consumption would accelerate, in particular in agriculture where the number of farmers would be almost halved, from 9.3 million adults in 2019 to 5 million in 2050, or from 42 percent of the workforce to 20 percent. AP would then be embarked on a "Farmer-Excluding" path (FE), where farmers are fewer in number but with an ever-growing income gap with non-farmers, as in the past decades (1980–2019) marked by a deep agrarian crisis, and ever-increasing agricultural and food subsidies to mitigate such negative impacts. The remaining farmers, while specializing in selected products, employ capital- and input-intensive techniques under export-oriented contract farming with multinational agribusinesses. However, this approach only exploits the best and city-centric lands, leaving fallow areas to expand and cultivated land to decrease. Despite a 6 percent annual growth in the agricultural GVA, the IA scenario faces challenges in food production and nutrition. With higher costs and lower nutritive quality, this vision falls short of the productivity and resilience witnessed in the AE scenario. Moreover, income disparities persist, with farmers earning substantially less than non-farmers. In order to bridge the income gap and support the unemployed, policies to reduce inequality entail significant financial costs, amounting to at least 18 percent of GDP in 2050. These policies, while aiming to mitigate the impact, ultimately lack the efficacy and holistic approach demonstrated by the AE scenario.

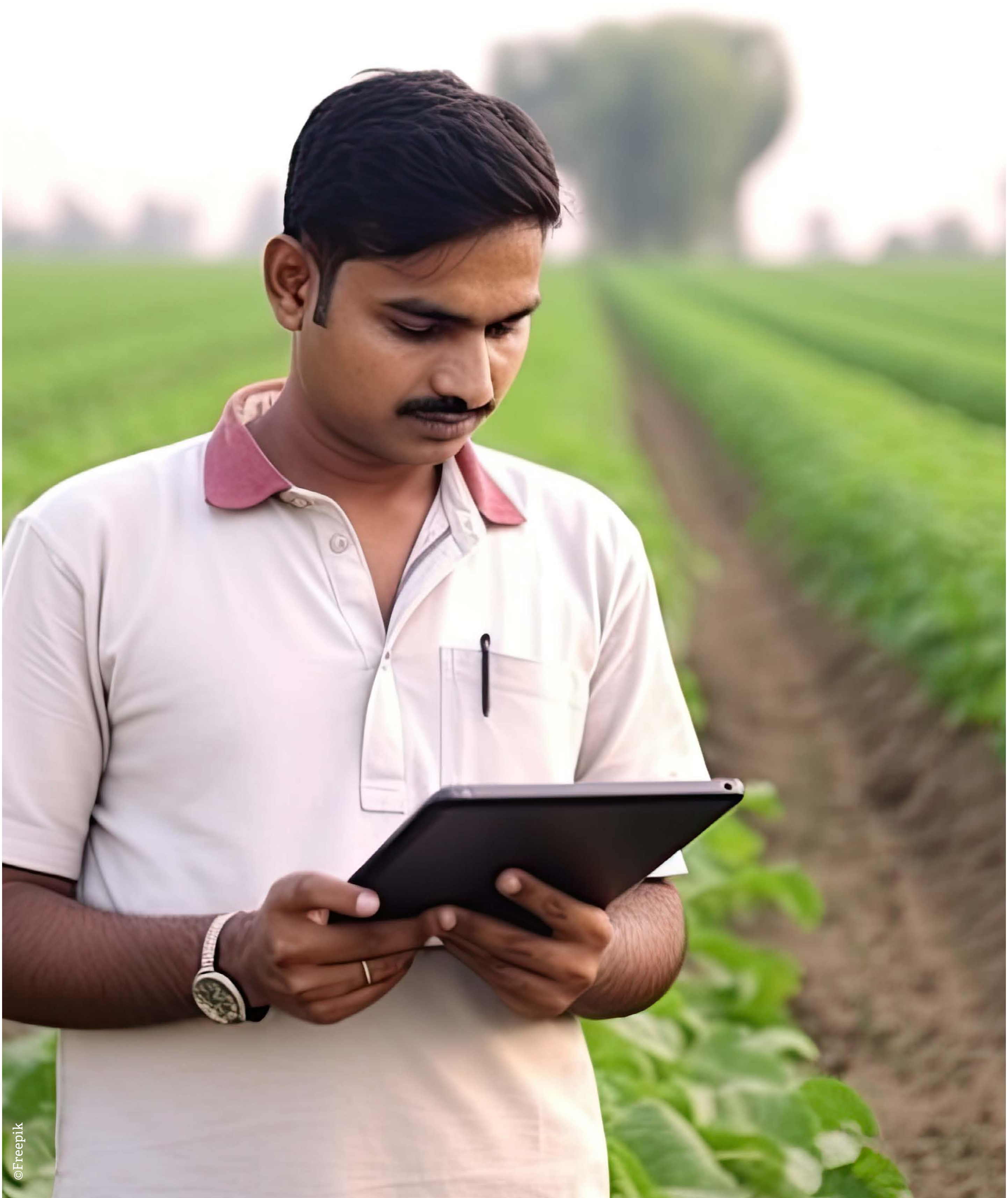
In both scenarios, the average income of farmers would be multiplied by about 5.5 compared to 2019 (all in constant INR 2011-12), to reach about INR 3 000 per day and per farmer (or nearly INR 1.1 million/year). Farmers would then earn almost the same, but for different reasons: in the IA scenario, farmers would produce more calories per hectare (almost 44 000 kcal/day against 36 000 in the AE scenario) and each on a larger area (1.11 ha/farmer on average against 0.83 ha in the AE scenario, and 0.67 ha in 2019), but at higher cost and lower nutritive quality. In the AE scenario, each farmer would earn 10.3 paise per kilocalorie produced, while it would be 6.1 paise in the IA scenario (moreover without deducting capital costs for machineries and others, much higher in the IA scenario).

However, a farmer–non-farmer income gap would remain in both scenarios. It would be less than in 2019, but would still represent 47 percent of the average income of IA farmers in 2050, and 22 percent of the average income of AE farmers (62 percent in 2019). In the AE scenario, capital-, energy- and water-intensive agriculture is not an option; the vision is that production of food and environmental services is more efficient when farmers operate at a small scale. But while small farm size makes agriculture more efficient and productive per hectare, it also prevents individual farmers from increasing their income through farm consolidation and robotization. To address this gap in the AE scenario, farmers could also be remunerated for the environmental services (currently unpaid) they provide when following agroecological approaches. This would help close the remaining income gap between farmers and non-farmers in 2050. With AE, these environmental services to local and global societies would be numerous, such as water saving and filtering, storage of soil organic carbon and mitigation of climate change, resilience to biotic and abiotic shocks thanks to highly biodiverse agroecosystems. Payments for Environmental Services (PES) could be granted to each farmer (whether cultivator or labourer) after evaluating and monitoring the extent to which their village or region practices agroecology providing multiple ecosystem and health services.

Overall, our two scenarios illustrate two possible but radically different visions of agricultural science and productivity, of societal goals and choices, with their own trade-offs and necessary transformations. Compared to the current techno-centric and capital-intensive industrial agriculture and food that the IA scenario would amplify, our Expert Group was predominantly in favour of the AE scenario, because this AE scenario would be:

- more productive in terms of useful biomass per inhabitant;
- more resilient to economic, climate and biotic shocks;
- more labour intensive than capital intensive;
- more profitable for farmer households since their input costs would be cut, their diverse, tasty, nutritious and healthy foods would be better priced on local and international markets, and their coproduction of environmental goods or services could be paid for their local or global values, such as safe water, biodiversity reservoirs, soil fertility, nutrient recycling, pollination, combat diseases or floods, mitigation of, and adaptation to climate change.

These multiple benefits of the AE scenario would enable India to foster sustainable agrifood systems with inclusivity at the core, leaving no individual or community behind. It would respond to pressing economic, social and ecological challenges, and help achieve multiple SDGs as well as meet several global commitments.



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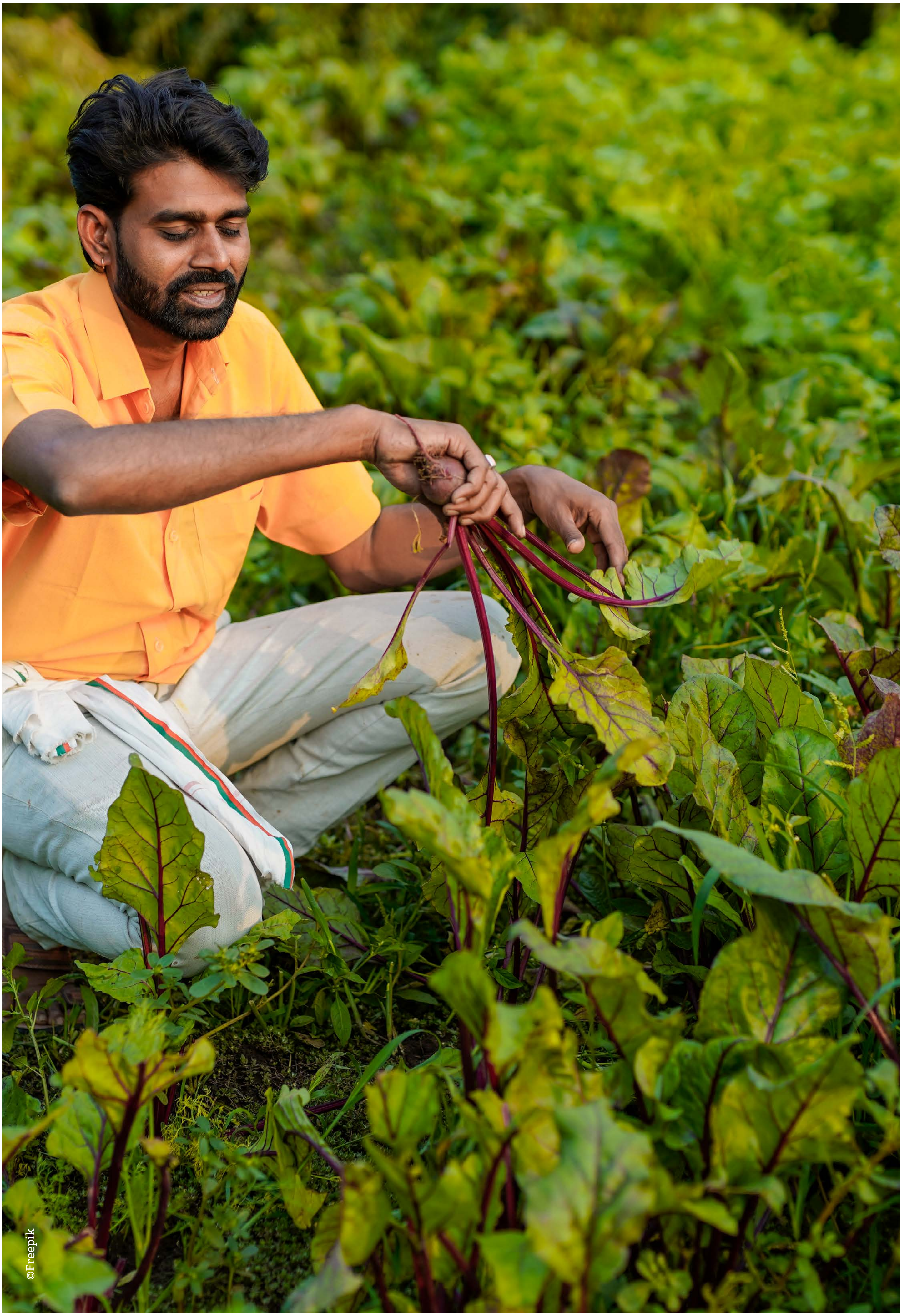


Annexes

1 . DATA SOURCES AND MANAGEMENT

1.1 Land use

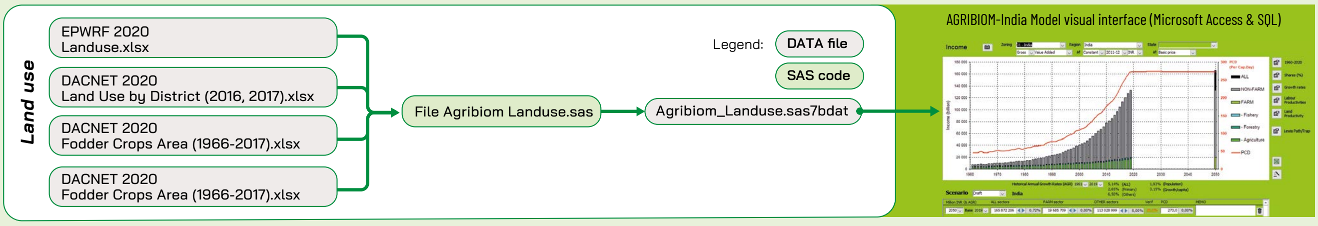
In every integrated model (combining economics and biophysics, such as IMPACT from IFPRI or GLOBIOM from IIASA), surfaces of land use (usually measured in hectares) are used for various purposes, such as estimating the potential of agricultural production, or more recently the emission of $CO_{2\text{-eq}}$ resulting from "land use changes" (LUC).[9] In Agribiom-India, data or assumptions on land use are primarily used to estimate:

- the total food production or the food yield per hectare in calories and/or macronutrients (production = cultivated area * yield);
- the agricultural labour productivity, in food calories or India rupees per hectare;
- the importance of irrigation (hence the importance of water consumption or energy subsidies to run water pumps);
- animal feed coming from agricultural and non-agricultural lands;
- other indicators such as human density. In the 2022 version of Agribiom-India, not all of these indicators could be estimated, in particular those related to animal feed, as well the carbon emissions resulting from LUC (which, however, seem rather low in India).

To scan the past evolution of land use/cover in India, we used the Indian official nomenclature and data mainly from EPWRF (2020). This nomenclature is more detailed than in FAOSTAT's historical series by country (FAOSTAT, 2022), with the exception of surfaces covered in fresh water (rivers, lakes, dams) which are not separated from the Indian category "area under non-agricultural uses". Indian state-wise statistics of land use suffer from many inconsistencies over the past years or decades (especially for Andhra Pradesh and North-Eastern states), and we have had to correct them as best we could. Figure 57 shows the input databases and the SAS code written to produce the output file "Agribiom_Landuse" with values for All-India and by State from 1961 to 2019.

In the Agribiom interface, the module "Land Use" (Figure 58) allows to instantaneously compute and visualize the evolution of the geographical area by category of land use (and other historical indicators: see combo boxes on the right side) in hectares, for a specific region (e.g. "Andhra Pradesh") of a "Zoning" area (partition of India from a State or a club of States to All-India), over the past decades and for a future scenario after entering the assumptions of the Expert group.

Figure 57. *Processing chain of land-use data in Agribiom-India*



Source: Dorin, 2023.

9 *These emissions may be important when forests (or even pastures) are converted into agricultural uses, and are subject to a special section in all reports of the Intergovernmental Panel on Climate Change (IPCC), called "LULUCF", for "Land Use, Land-Use Change and Forestry".*

Figure 58

Agribiom dashboard for land-use

Source: Dorin, 2023.

1.2 Population and employment

Populations and demographic projections (made by specialized demographic models) are key elements of any macroeconomic model, in particular for estimating past or future demand for food and other products or services. Nevertheless, these models often neglect employment and labour income, unlike in Agribiom-India where employment, labour productivity and farm–non-farm average income gap have been placed at the heart of the reasoning.

Agribiom-India studied, compiled, processed and compared different sets of state-wise data on population and employment by gender, age group, rural/urban zone, level of education, economic activity, main/marginal worker or work status (PS+SS):[10] the decennial Indian censuses from 1961 to 2011 (RBI, 2019; CMIE, 2020), the (usually) quinquennial NSS or NSO (2020) surveys on employment and unemployment from 1973 to 2019, and the quinquennial IIASA's population projections (KC *et al.*, 2018) from 2011 to 2101 (by gender, age, zone and education only). When necessary, some data has been re-estimated to obtain comparable category content over time, and all data have been linearly interpolated to obtain annual values during the periods considered. Figure 59 shows the input databases and the SAS codes written to produce two output files with values for All-India and by State: "Agribiom_Population" from 1971 to 2050 (with IIASA's population projections from 2011) and "Agribiom_Employment" from 1973 to 2011 (Census) or 2019 (NSO).

In the Agribiom interface (built under Access with SQL codes), the module "Population" (Figure 60) allows to instantaneously compute and visualize the evolution of population and employment (and other historical indicators: see combo boxes on the right side) in human heads (capita) for a specific region (e.g. "Andhra Pradesh") of a "Zoning" area (partition of India from a State or a club of States to All-India), over the past decades and for a future scenario after entering the assumptions of the Expert group.

10 PS = Principal Status (engaged in any economic activity at least 6 months per year); PS = Subsidiary Status (engaged in any economic activity from 1 to 6 months per year)

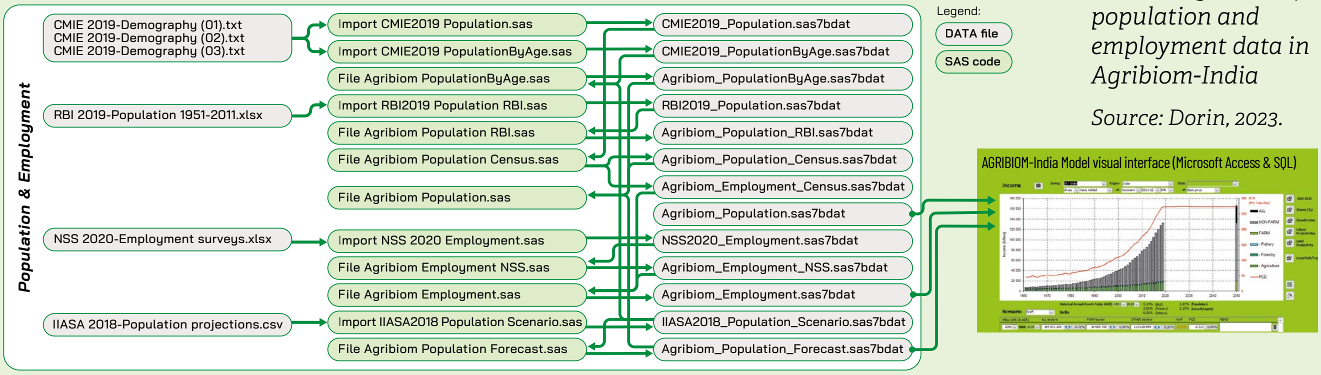


Figure 59

Processing chain of population and employment data in Agribiom-India

Source: Dorin, 2023.

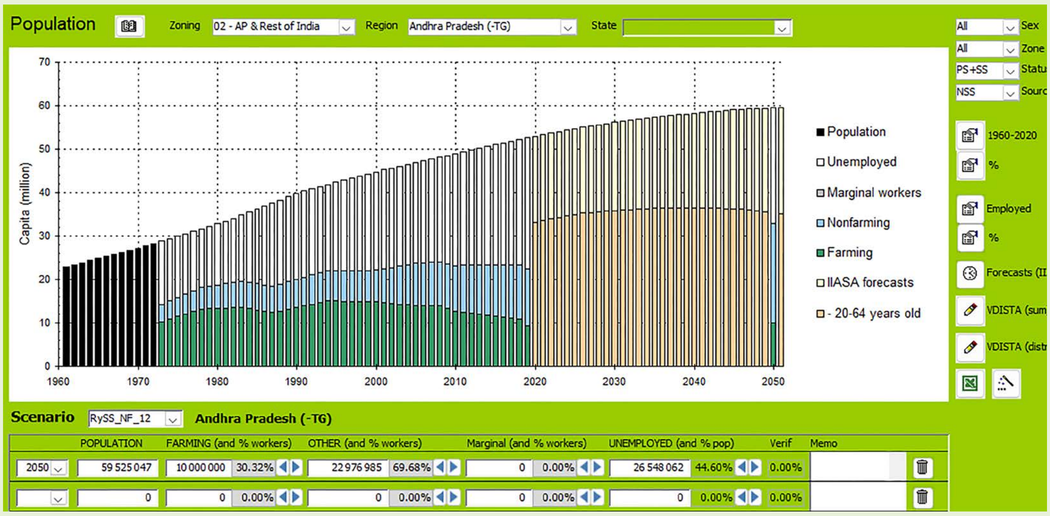


Figure 60

Agribiom dashboard on population and employment in India

Source: Dorin, 2023.

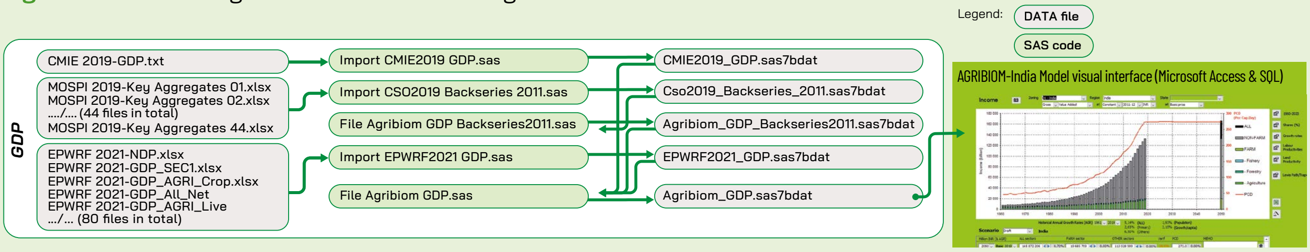
1.3 Economic growth and inequality

Most applied macro-economic models detail the different components of GVAs and optimize/maximize mathematically the GDP under various constraints (e.g. various levels of tax or subsidy on specific activities). This is not the ambition of Agribiom-India (no optimization/maximization), which mainly uses GVAs to study the evolution of income in two broad sectors of activity, “farm” and “non-farm”, and the average gap in “labour productivity” between these two sectors as a proxy of income inequality.

For past statistical series, unique work was carried out to: compile and scan different indicators (GDP/NDP, GVA/NVA) by sector at current and constant prices according to different bases (2004–05 and 2011–12); create 2011–12 based series by State from 1980 to 2019.

Figure 61 shows the input databases and the SAS codes written to produce the output file “Agribiom_GDP” with values for All-India and by State, from 1980 (or 1961 for All-India) to 2019. In the Agribiom interface (**Figure 62**), the GDP/Income module allows to instantaneously compute and visualize the evolution of Gross/Net Domestic Product or Value Added (and other historical indicators: see combo boxes on the right side) in current or constant prices, base 2004–05 or 2011–12, for a specific region (e.g. “Andhra Pradesh”) of a “Zoning” area (partition of India from a State or a club of States to All-India), over the past decades and for a future scenario after entering the assumptions of the group of experts.

Figure 61. Processing chain of GDP data in Agribiom-India



Source: Dorin, 2023.

Figure 62

Agribiom dashboard on gross value added

Source: Dorin, 2023.

1.4 Food production and yield

In 2006, on the basis of hundreds of thousands of FAO commodity balances in tonnes, Agribiom was the first to estimate annual food balances[11] in calories, from the country to the global scale, over several decades (1961-today) and for three biomass origins (plant, animal, aquatic) (Paillard *et al.*, 2011 (2014: Springer)). This led, for example, to estimate and compare the annual productivity of land and labour in plant food calories, and to realize how much the latter two were evolving and differing from one region of the world to another, particularly between OECD countries and the others due to very different path of structural transformation (Dorin, 2017, 2022). It also helped to assess how much certain countries or regions of the world relied on imported animal feed, or their degree of food self-sufficiency to cover their food demand (Paillard *et al.*, 2011 (2014: Springer)).

With Agribiom-India, such an exercise could not be fully replicated due to non-existent statistics at Indian state level to estimate each element of the balances, for example the quantities of food used for animal feed and, above all, the Indian states' food trade with each other and abroad. We were nevertheless able to estimate production in food calories (as well in carbohydrates, proteins and fats) despite great difficulty in accessing consistent historical statistics by state on the various plant, animal and aquatic productions. In total, we used 48 product lines (Table 17) from the agricultural year 1974–75 until the year

11 Production + Import – Export +/– Stock variation = Food + Seed + Feed + Waste + Nonfood use (see Section 2.1)

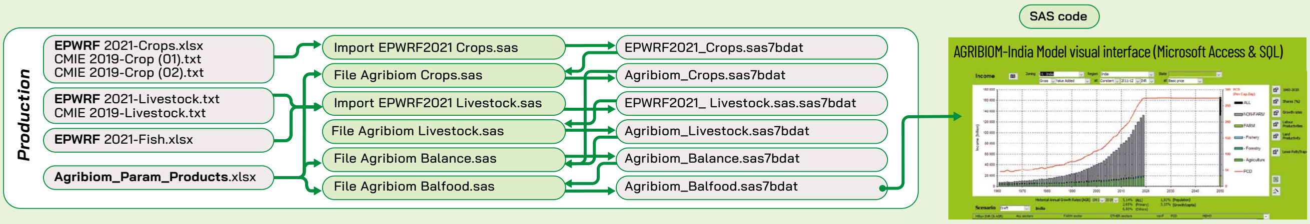
2019–20, but with missing lines, in particular for condiments and spices and, above all, for fruits and vegetables (low in calories but rich in fibres and micronutrients) due to non-existent or late statistics.[12]

The only exception for the year of departure is for meat production (from ruminant and monogastric animals), for which production statistics by Indian state usually start from 1998–99 (and not 1974–75), moreover with gaps or inconsistencies from state to state (some values therefore had to be corrected or deducted afterwards).

Once the annual state production volumes (in tonnes or in number) were available, verified and/or corrected, they were each multiplied by their nutrient factor (i.e. contents in calorie, protein, fat and carbohydrate per 100g of product), found wherever possible in the Indian Food Composition Tables (Longvah *et al.*, 2017), else in the Food Composition Table "for International Use" of the FAO (2001). Due to different product lines, but also nutrition factors, different results were to be expected between Agribiom-Word and Agribiom-India for the country India. It turns out in fact that these differences are relatively limited: for example, less than 5 percent in 2019 with regard to the production of plant calories (see **Section 3.4**).

Figure 63 shows the input databases and the SAS codes written to produce the output file "Agribiom_Balfood" with values for All-India and by State, from 1974 to 2019. In the Agribiom interface (**Figure 64**), the production module allows to instantaneously compute and visualize the evolution of food yield (and other historical indicators: see combo boxes on the right side) in daily kilocalories per hectare, for a specific region (e.g. "Andhra Pradesh") of a "Zoning" area (partition of India from a State or a club of States to All-India), over the past decades and for a future scenario after entering the assumptions of the group of experts.

Figure 63. Processing chain of food production data in Agribiom-India.



Source: Dorin, 2023.

Figure 64

Agribiom dashboard on food production/yield

Source: Dorin, 2023.

12 For example: we found consistent production of apples, tomatoes, cabbages, cauliflowers, grape, guava, Lady's fingers, lemon, litchi, mango, oranges, pineapples, sapota, or brinjal by state from 1991–92 only, that would distort the analysis of historical trends.

Table 17. Lines of edible products uses in Agribiom-India for estimating production in calories and macro-nutrients (1974–2019)

	Agribiom Product Code	Agribiom Product Name	State-wise statistics since:
Cereals	11 110	Rice	1962
	11 120	Wheat	1962
	11 130	Barley	1962
	11 210	Maize	1962
	11 220	Pearl millet	1962
	11 230	Sorghum	1962
	11 240	Finger millet	1962
	11 250	Small millets	1962
Pulses	12 110	Gram, Bengal	1962
	12 120	Gram, red	1962
	12 130	Gram, black	1970
	12 140	Gram, green	1970
	12 150	Gram, lentil	1970
	12 160	Gram, horse	1970
	12 210	Peas	1976
	12 220	Pea, grass	1970
	12 310	Bean, kidney	1970
	12 800	Guarseed	1966
Sugar	13 110	Sugar cane	1962
Oilseeds	14 110	Rapeseed-Mustard	1962
	14 120	Soybean	1976
	14 130	Groundnut	1962
	14 140	Sesame	1962
	14 150	Sunflower	1976
	14 160	Niger	1965
	14 170	Safflower	1966
	14 210	Castor	1962
	14 220	Linseed	1962
	14 310	Cotton, seed	1971
	14 340	Coconut	1965
	14 810	Cashew	1962
Fruits	15 410	Banana	1962
Vegetables	16 110	Potato	1962
	16 120	Onion	1978
	16 130	Tapioca	1962
	16 150	Sweet Potato	1962
Milk	21 110	Milk, cow	1973
	21 120	Milk, buffalo	1973
	21 130	Milk, goat	1973
Eggs	22 000	Egg	1973
Meat	23 111	Meat, cattle	1998
	23 112	Meat, buffalo	1998
	23 113	Meat, goat	1998
	23 114	Meat, sheep	1998
	23 121	Meat, pig	1998
	23 122	Meat, poultry	1998
Fishes	31 110	Fish, marine	1974
	31 120	Fish, freshwater	1974

Source: Dorin, 2023.

1.5 NITI Aayog projections toward 2033

In February 2018, NITI Aayog published its "*Demand & Supply Projections Towards 2033: Crops, Livestock, Fisheries and Agricultural Inputs*" (NITI Aayog, 2018). To better understand these projections and their assumptions, as well to see how their annual growth rate (AGR) would differ from our AgroEco2050 scenarios, we converted their all-India results (demand and supply projections in tonnes by group of commodities) into food calories using the nutritive factors of Agribiom-India (see previous section). For the food production, we obtained the results shown in **Table 18**, and in **Figure 65** for the plant food production only.

This exercise leads us to the following three remarks:

- In 2019-20 for All-India, our estimates in plant food production are rather closed to NITI Aayog projections (i.e. 4 100–4 400 Gkcal/day, with palm oil excluded in both sources) despite quite different values for oilseeds and fruits and vegetables (**Figure 65**).
- Within 12 years (2020–2032), NITI Aayog is very confident in the continuation of past production growths, and even their acceleration: the growth of plant food production would be 2.7 percent per year between 2020 and 2032 whereas, according to our estimates, it was only 2 percent between 1990 and 2019 (2.5 percent since 1980); unless these supply projections include imports to meet projected food demand (but this does not appear to be the case).
- Over a longer period (2020–2050, i.e. 30 years), our AgroEco2050 foresight exercise for Andhra Pradesh was much less confident in continuing past Green Revolution growth, for a multitude of reasons set out in the book (plateauing yields, depletion of natural resources, rising costs of industrial inputs and falling marginal productivity, greater frequency of extreme climatic events, etc.): in our most productive scenario (NF/AE scenario), the plant food production would grow by 1.4 percent per annum over 2019–2050.

Table 18. Projections of Indian food production towards 2033 from NITI Aayog, converted into calories (Gkcal/day)

(Gkcal/day)	2020	2028	2032	Annual growth rate (%) 2020-2032
Plant	4 084	5 040	5 634	2.72
• Cereals	2 536	2 993	3 259	2.11
• Oilseeds	577	779	916	3.92
• Pulses	165	208	237	3.03
• Sugars	347	399	427	1.75
• Fruits & Veg	458	661	795	4.69
Animal	643	966	1 194	5.29
• Milk	570	812	969	4.52
• Eggs	22	35	44	5.79
• Meat	51	118	181	11.17
Fish	25	36	43	4.63
Total	**4 752**	**6 041**	**6 871**	**3.12**

Source: Dorin, 2023, using NITI Aayog. 2018. Demand & Supply Projections Towards 2033, New Delhi, Government of India.

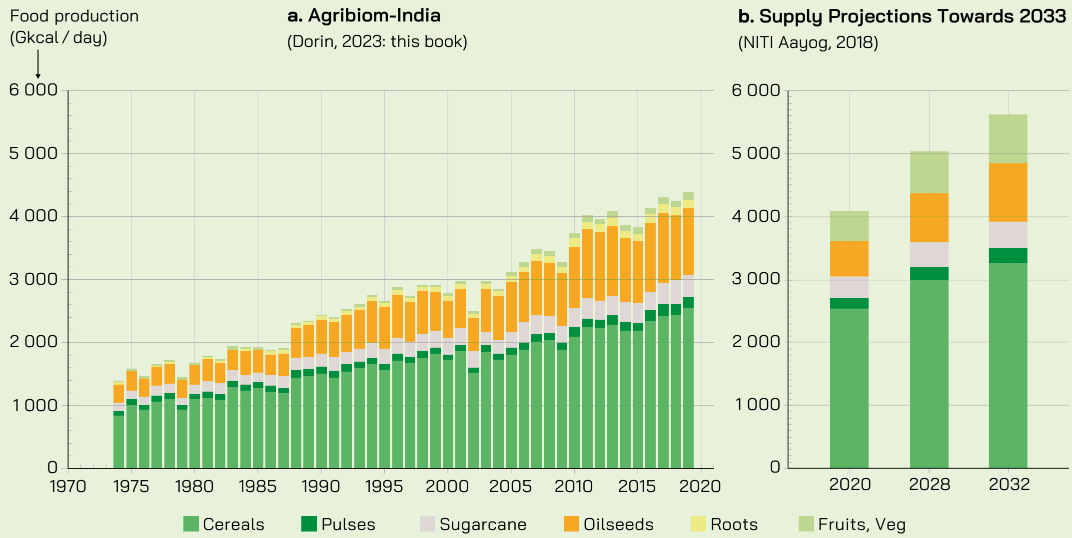


Figure 65

Plant food production in calories, past (1974–2019) and NITI Aayog projections (2020, 2028, 2032)

Source: Dorin, 2023, using NITI Aayog. 2023. Demand & Supply Projections Towards 2033, New Delhi, Government of India.

2. ANDHRA PRADESH COMMUNITY-MANAGED NATURAL FARMING (APCNF) IN A NUTSHELL

To address the farm distress and impending climate change, Government of Andhra Pradesh (GoAP) has been working towards transforming agriculture and food systems to agroecology based Natural farming (NF). Rythu Sadhikara Samstha (RySS), a section 8 company under GoAP has been mandated to implement the Andhra Pradesh Community-managed Natural farming programme (APCNF). The programme initiated with 704 villages in 2016 and has since then gained traction across the state, nation and globally.

APCNF is all about farming in harmony with nature, and firmly believes that nature has solutions to all kinds of human-induced problems in agriculture and food sector. As an alternative to the current agriculture practices, APCNF has emerged as a transformational technology. It safeguards our collective future by:

- Reducing costs of cultivation and risks, and increasing yields thereby generating regular income. It is climate change resilient, thereby lesser risks in farming;
- Producing more food, safe and nutritious food that is free of chemicals;
- Reducing the migration of youth from villages and is creating reverse migration to villages;
- Enhancing soil health, water conservation, regenerating coastal ecosystems and biodiversity.
- While Natural farming is a paradigm shift, transfer of Natural farming technology is challenging and calls for saturated transformation of a village rather than converting a single farmer or single farm.

In this context, APCNF's theory of change works towards these important elements:

- Transformation in a democratic way wherein women collectives (Self-Help Groups and their federations), farmers institutions are involved in programme planning, implementation and monitoring;
- Knowledge dissemination and handholding support constantly provided through farmer-driven architecture led by Community Resource Persons (CRP); and
- Saturation of entire village, cluster, mandal (sub-district unit) and the state; converting all villages, all farmers, all farms and all practices leading to a total transformation.

By April 2020, 695 000 farmers[13] in Andhra Pradesh had been partially or totally practicing natural farming, on 190 000 ha spread over 3011 villages, scattered over all the 664 mandals of the State (Dorin, 2022). As of October 2023, APCNF reported to be operational in 3730 villages and to have enrolled 851 000 farmers across the 26 districts covering an area of 278 000 ha, 90 percent of which are small and marginal farmers and members of SHGs. The women SHGs are very actively involved in implementation of natural farming by each member right from planning, implementation and monitoring, knowledge dissemination, collective preparation of inputs, finance required for practicing natural farming etc. As of October 2023 the programme reported 140 000 women SHGs in 5 386 Village Organizations across the state, which are very actively engaged in APCNF. The intervention of homestead vegetable gardens has served as a very good entry point activity to get APCNF introduced to the most vulnerable families, the landless farm workers, thereby facilitating their graduation towards leasing land for practicing NF.

13 The 695 000 farmers include 442 000 "cultivators" (owners or tenants of agricultural land) and 253 000 "agricultural labourers" (workers without land except a kitchen garden).

The programme intends to reach all 6 million farmer families by 2031.

The funding of the programme comes from the central sponsored schemes of Paramparagat Krishi Vikas Yojana (PKVY) and Bharatiya Prakritik Krishi Paddhati (BPKP) programmes of Government of India. These funds are utilized for supporting the field level transformation. Funding support for innovations, technical support, strategy, leadership, partnerships, research and other aspect of programme comes from support from donors and philanthropies namely Azim Premji Foundation (supported with USD 12.1 million in phase 1 and USD 7.8 million crores in phase 2, Co-impact Foundation [USD 15 million] along with loan and grants from KfW Bank Germany (USD 90.6 million loan). The programme also operates on several agendas via partnerships between entities nationally and internationally including FAO, University of Ready, CIRAD, ICRAF, Niti Aayog, MANAGE, etc. The GoAP has set up a separate Department of Natural farming to ensure greater focus on Natural farming.

There is critical focus on research, evidence and learning in the programme. To enable this to happen on a more systematic basis, the Indo German Global Academy for Agroecology Research and Learning (IGGAARL) has been established in 2022. The Academy is supported by a grant of EUR 20 million from the Government of Germany.

While farmer transformation to climate resilient, natural farming is at the centre of the programme, there is crucial work happening with respect to health and nutrition counselling and support for pregnant women, nursing mothers and infants. There is significant work happening on value chains. Given the increase in demand for organic produce and the fact that APCNF is the largest programme in India, major retail chains have come forward to have a partnership with RySS to assure a good price for farmers.

Seeing the inspiring work in Andhra Pradesh, many States have approached RySS for technical support. Accordingly, RySS is supporting Madhya Pradesh, Rajasthan, Meghalaya and Odisha. Many more States are likely to in initiating transformation in their States. the Central Government and other States are encouraged to ground Natural farming in their geographies. RySS has also been declared as the National Support organization to provide support to other states for grounding natural farming. The work of the programme has also crossed borders as other countries and international entities want to adopt APCNF model in their own areas.

3. AGROECO2050 PARTICIPANTS

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Tomio	Shichiri	FAO	FAO Representative in India
Anne-Sophie	Poisot	FAO	Agriculture Officer, Farmer Field School and Assistant Team Leader, Pest and Pesticide Management

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3.4 AgroEco2050 Project Team members

First name	Last name	Institution	Position
T. Vijay	Kumar	Rythu Sadhikara Samstha (RySS), Government of Andhra Pradesh	Executive Vice-Chair Ex officio Special Chief Secretary Natural Farming
Bruno	Dorin	CIRAD/CIRED	Senior Economist
Anne-Sophie	Poisot	FAO	Assistant Team Leader, Pest and Pesticide Management
Rakesh	Kapoor	FAO India (until December 2022)	Foresight Consultant
Jimena	Gomez	FAO (from January 2022)	Agroecology Expert
Nagi	Reddy Chinta	RySS	Senior Consultant
Swati	Renduchintala	RySS	System Change Associate Scientist with CIFOR-ICRAF deployed as Programme Manager in RySS

4. AGROECO2050 WORKSHOPS

4.1 AgroEco2050 Online workshops (2020-21)

a) Dates and agenda

15.09.2020	Virtual Expert Group Workshop 01	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.50	Welcome Address Opening Remarks Opening Remarks	Vijay Kumar, RySS Rajiv Kumar, NITI Aayog Ramesh Chand, NITI Aayog
15.50–17.00	Foresighting a full transition to agroecology in Andhra Pradesh: WHY? + Q/A Comments by Dr Rajiv Kumar (at 16.50)	Bruno Dorin, CIRAD
17.00–17.10	Health break	
17.10–18.15	Foresighting a full transition to agroecology in Andhra Pradesh: HOW? + Q/A	Anne-Sophie Poisot, FAO and Bruno Dorin, CIRAD
18.15–18.30	Closing Remarks Closing Remarks	Ramesh Chand, NITI Aayog Tomio Shichiri, FAO

15.10.2020	Virtual Expert Group Workshop 02	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.35	Welcome Address	Vijay Kumar, RySS
15.35–16.15	Zoom Poll Question 1	All participants
	Introductions by Participants. What is the "burning question" on your mind about this study?	All participants (maximum of 1 minute each)
16.15–16.25	Brief Recap of Last Workshop	Anne-Sophie Poisot, FAO
16.25–6.35	Open House: Questions and Answers	
16.35–16.45	Health Break	
16.45–17.55	The AP-CNF Vision and Q&A	Vijay Kumar, RySS
17.55–18.00	Comments by Farmer Saraswati	Saraswati Kommojula
	Zoom Poll Question 2	All participants
18.00–18.20	Breakout Groups (5 to 6 groups) for interaction. Groups will discuss: 1) The WHAT: What are the critical issues to be addressed in the study? 2) The HOW: What are your suggestions on the process of the study? Groups will report back (post–workshop) with a summary of their points in two PPT slides.	All participants
18.20–18.30	Zoom Poll Question 3	All participants
	Sharing thoughts through Chat wave and Conclusion	Bruno Dorin, CIRAD

26.11.2020	Virtual Expert Group Workshop 03	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.35	Welcome Address	Tomio Shichiri, FAO
15.35–15.45	Brief Recap of Last Workshop	Anne-Sophie Poisot, FAO
	Zoom Poll Question 1	All participants
15.45–16.25	Introduction to Foresight and Futures Studies in India (presentation and Q and A)	Rakesh Kapoor, FAO
16.25–16.35	Health Break	
16.35–18.15	The Agribiom Quantitative Model for AgroEco2050 (presentation and Q and A)	Bruno Dorin, CIRAD
18.15–18.20	Zoom Poll Question 2	All participants
18.20–18.25	Zoom poll Question 3	All participants
	Chat-wave	Vijay Kumar, RySS
18.25–18.30	Closing Remarks	

24.02.2021	Virtual Expert Group Workshop 04	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.35	Welcome Remarks	Vijay Kumar, RySS
15.35–15.40	Introduction to WS4 – what is expected from the workshop	Anne-Sophie Poisot, FAO
15.40–16.40	Applying the TEEB Agri Food Framework to Evaluate Farming Models in Andhra Pradesh Presentation and Q and A	Pavan Sukhdev, GIST and WWF International, and Nachiketa Das, GIST
16.40–16.50	Health Break	
16.50–18.10	Individual Presentations by five EG members: Towards outlining the scenarios – sharing possible visions of food and agriculture in Andhra Pradesh or/and India by 2050 Q and A on all presentations	Srijit Mishra Arabind K. Padhee Saraswati Malla Reddy Richa Kumar
18.10–18.30	Open house and Discussion about the process forward for two physical workshops	Chaired and moderated by Vijay Kumar, RySS and Anne-Sophie Poisot, FAO

27.04.2021	Virtual Expert Group Workshop 05	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.35	Welcome Address	Vijay Kumar, RySS
15.35–15.45	Brief Recap of Last Workshop	Anne-Sophie Poisot, FAO
15.45–16.10	Two Scenarios for Andhra Pradesh 2050 and Q and A	Rakesh Kapoor, FAO
16.10–16.45	Presentations by Expert Group Members and Q and A (moderated by Anne-Sophie Poisot)	Subhash Garg Ajay Jakhar
16.45–16.55	Health Break	
16.55–18.15	Presentations by Expert Group Members and Q and A (moderated by Anne-Sophie Poisot)	Ranjit Kumar G. Poyyamoli Rajeswari Raina G. V. Ramanjaneyulu A. Ravindra
18.15–18.30	Concluding discussion	All participants, moderated by Vijay Kumar, RySS and Anne-Sophie Poisot, FAO

24.05.2021	Virtual Expert Group Workshop 06	Speakers
15.15–5.30	Participants join the meeting online	
15.30–15.35	Welcome Remarks	Vijay Kumar, RySS
15.35–15.50	Brief Recap of Virtual Workshop 5	Anne-Sophie Poisot, FAO
15.50–16.40	"What does agroecology mean to you? A strategic overview and its practical implications" and Q and A	Fergus Sinclair, CIFOR-ICRAF
16.40–16.50	Health Break	
16.50–17.40	Presentations by Expert Group Members and Q and A (moderated by Anne-Sophie Poisot)	Kavitha Kuruganti C. Shambu Prasad
17.40–18.20	Discussion on the presentation made during WS5: Andhra Pradesh 2050: Elements towards Two Scenarios	All participants, moderated by Rakesh Kapoor, FAO
18.20–18.30	Concluding discussion	All participants, moderated by Vijay Kumar, RySS and Anne-Sophie Poisot, FAO

29.06.2021	Virtual Expert Group Workshop 07	Speakers
15.15–15.30	Participants join the meeting online	
15.30–15.35	Welcome Address	Tomio Shichiri, FAO
15.35–15.50	Brief Recap of Virtual Workshop6	Anne-Sophie Poisot, FAO
15.50–16.40	Talk/Presentation by Ashok Dalwai on The Future of Agriculture in India and Q and A	Ashok Dalwai, CEO, National Rainfed Area Authority, Ministry of Agriculture and Farmers Welfare
16.40–16.50	Health Break	
16.50–17.40	Presentation on Andhra Pradesh 2050: Elements towards Two Scenarios – Revised version, followed by discussion	Rakesh Kapoor, FAO
17.40–18.10	Concluding discussion and information on next workshops	All participants, moderated by Vijay Kumar, RySS and Anne-Sophie Poisot, FAO

b) Expert presentations during the online workshops

Name	Dr Rajiv Kumar
Date	WS01 – 15.09.2020
PPT	No – Opening Remarks
Synthesis	

There are two existential questions facing us in our country specially and all over the world. One question is the future of the farmer - because still 45 to 65 percent of people are dependent on the rural sector, etc. What is the paradigm shift we need to ensure the future of the farmers?

Two, the future of the planet itself! We are already in, or are rapidly approaching, an emergency where the planet will not be able to bear the footprint that we are imposing on it – in terms of use of water, carbon content in the atmosphere, or the use of chemicals 5, which have an impact on health of the soil as well as on the health of the human beings and of our rivers, oceans and so on.

On both these levels, natural farming, as propagated by Mr Subhash Palekar and the team led by Mr Vijay Kumar and others, is the answer to both these existential questions! That's a very big assertion and Dr Kumar hoped that this panel of experts will ask tough questions and help us to either disprove or prove this hypothesis.

We have to commend the amazing achievements of the Indian farmer and the Indian agro-scientific community (with the green revolution at the head of it) for reaching here from the level where we were living from ship to mouth! Thanks to them, we not only have 70 million tonnes of food grain in stock, but we also have our distribution channels in place to make sure that the food reaches everyone now, although there is probably incipient or disguised hunger in some places.

But this kind of intensive, chemical-based agriculture has run its course and is now at the end of its tether. The issue of small holdings is important and my colleagues in NITI Aayog have shown that India agriculture in its current form is globally uncompetitive. The yields are very low, the possibilities and the options of large-scale mechanizing agriculture are not feasible. We need to shift gears and stop emphasizing production – the key is to take the necessary steps to double or triple or quadruple the farmers' incomes so that there is not a movement away from agriculture and the children of farmers don't want to be farmers.

Dr Kumar's own experience has shown, he said, that by practicing natural farming, even as city-based part-time farmers, some money can be made because they no longer use chemical inputs and there is demand for the chemical-free output. The natural farming approach is promising to tackle the issues of the distressed, indebted farmer. India can emerge as an agro-exporter, as an exporter of high value agro-processed products if we take to this type of farming, he said.

He asserted that this type of farming is good not just for farmer incomes – it has the potential to double and increase it significantly – but also for his health and for the health of the people and consumers. He said that he has seen it with his own eyes in Himachal, Andhra, Madhya Pradesh, U.P., etc.

On the second question, the biggest existential question facing the planet, Palekar Saheb's way of doing natural farming releases the micronutrients in the soil and increases the population of microorganisms hugely in the soil, which otherwise are destroyed by the use of chemicals. Also, it helps to create the humus which then fixes water from the moisture. So, the water use and water extraction from the ground that is prevalent in 90 percent of Indian agriculture goes down significantly. In addition, the organic carbon content in the soil increases significantly, as shown by Hissar Agricultural University. So, it could be the largest carbon sequestration programme going if you adopt this form of agriculture. You can bring back the carbon into the soil, reduce the water content, reduce chemical runoff and consumption and make our rivers better.

This package, therefore, offers you the best ecological answer to reverse climate change and it is marginal and poor farmers with small holdings who can benefit from this. The only shortcoming is that the labour input probably increases because this is labour intensive. But because of the practice of mulching (*chhaggan)*, the growth of the weeds comes down so the labour intensity required comes down.

Dr Kumar said that he will leave it to the experts involved in this study to tell us how to replicate it on a scale that can actually make an impact, not only for the Indian farmer but for the planet as a whole.

Comments by Rajiv Kumar after Bruno's presentation: Prof. Bruno Dorin's presentation is remarkable and has great analytical depth. It couldn't be clearer today that Asia, especially South Asia and India, really has no option but to make a paradigm shift in agriculture. We cannot pursue industrial agriculture in this country – Indian agriculture today needs a complete transformation. Dr Kumar said he has become a votary of the so-called zero budget natural farming, which is a very important option. We need market-based agriculture and agriculture which is free of government intervention, except for promoting and facilitating the transition from industrial agriculture to natural agriculture, to agroecological agriculture.

We need to discuss how to scale what we have already in Andhra and Himachal Pradesh. We need to know how to handhold the farmer and achieve the transition – that will be the key. NITI Aayog and the country will be very grateful, Dr Kumar said, if this study could tell us how to achieve this transition.

Name	Prof. Ramesh Chand
Date	WS01 – 15.09.2020
PPT	No – Opening Remarks
Synthesis	

He commended the robustness of the presentation of Dr Dorin, whom he has known for a long time and who has strong academic credentials. He indicated that agriculture in India is not accurately represented by the national accounts and statistics, which are purely financial calculations. The financial data diminishes the value of agriculture in the Indian context and also globally, because it does not capture the importance of agriculture for humanity, the basic contribution to food, nutrition and survival, and does not consider the positive role it plays for ecology.

Regarding the scenario of a world without farmers with only three percent of the population are engaged in farming. Prof. Chand said that we do not know whether it is because we have followed industrial agriculture, or it is due to other kinds of developments outside agriculture. He said that we have to exercise caution about the attribution of causes. It would be wrong to attribute the conditions/results in the stage that we have reached or we are likely to reach in the future solely because of the kind of agriculture we practice in this country. There are three major sectors and factors ultimately influencing the results and the outcome: the agriculture sector, the industry sector, and technology. How the other two sectors behave also determines what happens in agriculture. In fact, after a stage, the fate of agriculture (i.e. the fate of farming and income of farmers, agriculture labour, etc.) depends more upon what happens outside agriculture than what happens inside. Today the industry depends more on capital intensive machinery, robotics, artificial intelligence – all these kinds of things. The employment situation is worsening because of these developments, not because of agriculture. The children of farmers are looking for jobs outside agriculture, but the jobs are not available.

For instance, in the case of Punjab, the reality is that it is not the green revolution or agriculture that failed Punjab, it is the industry and the policies of the government that have failed Punjab. In other words, many of the ills we are attributing to agriculture are not because of the nature of agriculture, they are because of the wrong choices made by human beings who are practicing agriculture.

India has enormous diversity in population and local culture, and thus great variety and difference in food habits and the food basket. Prof. Chand suggested that using calories as a unit of measurement has serious implications for a country like India. If you are using the kilocalorie as a unit then you will be biased towards carbohydrates, meat, milk, etc. but you will be biased against fruits and vegetables, which have other kinds of nutrients but few calories and hardly any protein. Prof. Chand suggested that a better alternative would be the prices of a particular year, constant prices rather than calories.

And prices may also become less relevant over time because of a change in ratios but still, he felt, that using prices is more appropriate and has fewer limitations as compared to using calories. He said it is because of the use of the calorie as a unit that, in Bruno's presentation, the rate of growth in agriculture is being shown as lower that the three percent or so growth that has actually been the case for India in the last decade.

Regarding the objectives of the foresight study, Prof. Chand suggested that three scenarios are important to look at in the future. One is the extreme that you do not care about what is happening to natural resources, the environment, so you just go for industrial agriculture or chemical agriculture. The second scenario is what we are preaching under Sustainable Development Goals – the middle path – that nature has some resilience and has some assimilative capacity. You can release some greenhouse gases to the extent that nature assimilates these kinds of things. You can release some chemicals and pollutants into the environment to the extent that the assimilative capacity of the environment keeps absorbing it. You can pump out water at certain rates, without over-pumping, which can be sustained. This is modern agriculture but with sustainable use of inputs.

The third model, which we are now talking about, is no external input natural farming or zero budget farming or different variants of it. The foresight study being undertaken is very timely and interesting because the world, and also India, is now looking for alternatives. It makes sense to look for alternatives because with the 3 percent growth in agriculture domestic demand is not keeping pace. Prof. Chand said his calculations show that domestic demand is growing at 2.2 percent – so it would not be any serious threat to food security even if you shift 20 percent of the area towards natural farming. In the short term this may involve some healing penalty, but it is worth experimenting and trying.

It appears to him, Prof. Chand said, that the middle path is the most likely and the path on which humanity has to rely. A combined methodology strongly rooted in optimal exploitation of natural resources (Stiglitz Models) such as soil, water, power, etc. which integrates best practices from modern agriculture and natural farming, could be the path forward to a sustainable future.

Prof. Chand felt that this foresight study would be very helpful in framing policies and making adjustments to change the development pathways. He concluded by saying that he spoke in a slightly provocative manner to stimulate thinking but he does not intend to diminish the value of the great work that this study is doing.

Name	Dr Bruno Dorin and Ms Anne-Sophie Poisot
Date	WS01 – 15.09.2020
PPT	Yes
Synthesis	

The two broad objectives of our project, Bruno said, are:

(1) to develop a comprehensive and credible full-scale scenario of NF in AP

(2) to contribute to state, national and international debates and researches on agroecology

Bruno began with the theory of modern economic growth, which considers the farm sector to be backward and the non-farm/ urban sector to be modern, skilled and innovative. The OECD countries are now in what has been called a "World Without Agriculture" with agriculture contributing not more than 3 percent of employment and 3 percent of GDP. The two questions before us are whether this is a desirable scenario in India and other developing countries; and whether this scenario is even possible. "Can India and its States also follow this kind of modern economic growth?" Bruno said the answer is clearly no, or at extremely higher economic, human and environmental costs than for the OECD countries.

Discussing the dynamics of farm labour productivity and land availability in different parts of the world for the period 1961 to 2007, and with projections for 2006 to 2050, Bruno showed the historical evolution and future projections for active population in agriculture and income gap between farmers and non-farmers for different parts of the world. While Western EU managed to remove so many people from its agricultural land because of various factors, which he discussed. In India, contrary to the mainstream paradigm of structural transformation of the economy, the active population in agriculture has actually been increasing along with an increasing income gap between farmers and non-farmers; and these trends will not radically change by 2050. Thus, the Indian agrarian crisis won't be solved with industrial agriculture, or at very high socioeconomic/health/ environmental/public costs (including massive urbanization on a scale unprecedented in human history). Small-scale agroecological farms (such as Natural Farming in AP) could be an alternative to mega-slum-urbanization, and could give India a comparative advantage in the long run.

Name	Dr Bruno Dorin and Ms Anne-Sophie Poisot
Date	WS01 – 15.09.2020
PPT	Yes
Synthesis	

This second part of the presentation focused on the "How".

Bruno focused first on the methodology to be followed by the study. As in the French foresight exercise "Agrimonde", our foresight project is based on a 3-component platform:

- A Think-Tank (Expert group)
- debating some scenarios
- using a quantitative tool called "Agribiom"

....and the expertise of its members (Expert group)

The foresight platform with various experts and stakeholders from different backgrounds – academia, farmers, government, civil society and international organizations will:

- firstly, revisit and discuss collectively the past evolutions since the 1960s;
- secondly, build/discuss/compare a least two contrasted scenarios, e.g.: Business as Usual (or "trend scenario") versus. Natural Farming.

The study will be carried out through the quantitative tool/model "Agribiom" under development to deal with Indian issues and data. The methodology is based on the past global foresight exercise "Agrimonde: Scenario and Challenges for Feeding the World in 2050" (Book in English published by Quae in 2011, then in 2014 by Elsevier). Bruno informed that, up to now, there have been two Agrimonde foresight exercises, both at the global level: the first from 2006 to 2010 in, where he was in the forefront, and a second one from 2012 to 2016, focused on land use and which involved a very large panel of international experts.

For our Foresight Study, in order to apply the quantitative tool/ model "Agribiom" (Dorin and Joly, 2020) to India, an important and time-consuming data collection and modelling are underway from the 1970s in many fields (from land use to diets), as well as the building of a model interface for screening and discussing past evolutions and future scenarios with the expert group during workshops. Two scenarios for 2050 ("Business as Usual conventional farming" and Natural Farming) could be imagined and quantified consistently through such a collective participative process.

After this, Anne-Sophie Poisot (FAO) presented the rationale, the background and the process of the study. She described how she and Bruno started working on the study in 2018 and discussed it with Vijay Kumar of RySS. Realizing the global

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crisis of conventional intensive industrial agriculture along with farmer distress and other social and environmental costs, Natural Farming explores an alternative path with healthy soils, no synthetic pesticides or fertilizers, biodiverse productions, SHG, Farmer-field schools, etc. It is considered part of the science, movement and practice of agroecology that is growing globally. Agroecology proposes a different model from the socio-technical regime of the Green Revolution (GR) and, more generally, from the paradigm of "modern economic growth" or "structural transformation" (in economics) that was followed by land-abundant OECD countries. Anne-Sophie summarized the debates and interest among FAO member countries regarding agroecology, and gave examples from a number of countries currently implementing policies on agroecology.

In Andhra and India, AP-ZBNF may help respond to the current deep crises: job-less growth, farmer over-indebtedness despite huge and unsustainable public subsidies (fertilizer, electricity, irrigation, credit, etc.), declining marginal productivity of industrial inputs, low labour productivity in agriculture and growing income gap with other working people, soil and biodiversity erosion, water pollution and groundwater depletion, large emission of greenhouse gases, unbalanced diets and nutritional insecurity, unsafe food, low resilience to growing economic and climate risks, etc. At the global level, AP-ZBNF could become the first example of "Scaling Up agroecology to achieve the Sustainable Development Goals", a central concern of the FAO.

In this context, the Foresight Study aims to provide an evidence-based, robust process to explore the implications that such agroecological transition may have, while at the same time, providing data and a space of dialogue to support policy decisions in the state.

Anne-Sophie discussed the methodology and process for the study. The timeline of the study is detailed in slide 43 of the attached pdf of the presentation made. Many of the initial tasks such as signing of agreements, hiring of staff and kick-off meetings have been accomplished. A substantial amount of work on the Agribiom India model and interface has been carried out. The major themes to be discussed in the longer, physical workshops to be held subsequently are:

Theme 1 - Population and Economic Growth

Theme 2 - Land use, crop/livestock productivities and health

Theme 3 - Food demand, other agricultural demand and trade

Theme 4 - Two scenarios for Andhra Pradesh in 2030/50

The expectations from Expert Group members are:

- Bring their respective disciplinary knowledge, experience, stakeholder perspectives and questions to help discuss, imagine and refine the scenarios for AP 2050 and their potential implications.
- Participate with an attitude of constructive criticism, open enquiry, respect for diverging views and explore the uncertainties and "maybes"
- Participate in all workshops (during 2020-2021) for consistency
- When public health situation will allow, participate in physical workshops (travel, accommodation and food supported by RySS/APPI)

Before physical workshops, notes summarizing literature and data on historical evolutions (since 1970s as feasible) of various dimensions of the Agribiom quantitative model shall be shared with the EG members.

Name	Ms Anne-Sophie Poisot
Date	WS02 – 15.10.2020
PPT	Yes
Synthesis	

Anne-Sophie Poisot (FAO) presented a recap of the presentations made in the last workshop, summarizing the key arguments and assertions made. The key points and arguments made, recounted by her, are:

We all face a wicked problem – a really complex problem – at the nexus of agriculture, food environment, society, poverty and climate, and we all would like to see agriculture being part of the solution rather than continuing to be part of the problem.

The central question for the study is where Andhra Pradesh will go by 2050. It is through the power of combining our questions and our insights that we will be able to come up with creative solutions and different perspectives. The study will attempt to harness the power of Socratic dialogue. That is why we started this meeting with the burning questions from everybody and in future meetings we will address these questions and look for answers together.

Bruno calls this a learning journey because in this ongoing process the assumptions will be built collectively not by two or three or four authors working behind their computers but it will be built by a series of stakeholders – all of us from different backgrounds and AgroEco2050 – Minutes EG Workshop 02 perspectives, and we will also build an interactive computer tool that will help us play with our hypothesis.

So this is really an exercise, somehow, in participative democracy and that's why we are very keen and happy to have so many high-level policymakers among our group and also to be feeding them on the results of this group. In the last workshop we had views from very senior policymakers about how this study is a bit of a laboratory they're looking at to better understand issues for India in particular and for the world at large.

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We have also tried to involve farmers in this journey of our foresight study and COVID-19 has stopped us in our tracks a little bit. We were developing a methodology on how we're going to have focus groups and how are we simplifying the language of the study to have meaningful discussions with farmers in Andhra Pradesh that will feed into our work.

Among the key points we made in the previous workshop is that in OECD countries agriculture has been operating through economies of scale, leading to what has been called a world without agriculture in these countries, where agriculture is just three per cent of the workforce and three per cent of the GDP. However, in India, Asia and large parts of Africa that's not happening. So this assumption that everybody is going to transition out of agriculture is not happening and the average farm size has declined and jobs are not being created in other sectors due to mechanization and automation. The income gap between farmers and non-farmers has been increasing, which is contrary to what has happened in OECD countries.

The assumption we have is that small-scale agroecological form may be an alternative to keep people on the land, based on certain exciting forms of knowledge-based agriculture, where farmers can also process food, transform the market, have ecotourism, etc. This would be an alternative to the mega slum urbanization that India would otherwise face.

This is where foresight comes in. We don't have the answers and we're not going to do forecasts, predict the future but we're going to explore the future. The French school of foresight says the best way to predict the future is to invent it and because we have policymakers and programme managers in this group the process itself will be a journey informing the action of all of us as a group. But this will be based on quantitative models to explore the possibilities.

Name	Mr T. Vijay Kumar
Date	WS02 – 15.10.2020
PPT	Yes
Synthesis	

Vijay Kumar presented the vision of APCNF – its rationale, how it evolved and the farming and socioeconomic scenario it envisions for Andhra Pradesh in the next few decades. The following paragraphs outline a summary of the presentation made by him.

There are several emergencies we are facing in Andhra Pradesh. There is, primarily, farmers' distress – low farmer incomes, especially in the rainfed areas due to droughts and even recurring losses and farmer suicides. Then there are consumers' health issues and the negative impact on the environment – soil, water, biodiversity and air pollution. So, we actually took up natural farming to protect farmers' livelihoods both in the drought-prone areas and also in the tribal areas. In the irrigated areas the serious issue is the problem faced by tenants. So different locations have different dimensions of the agriculture distress but one common distress is that year after year costs are increasing and returns are uncertain.

Tragically, land management itself is responsible for the problems we are facing. The problems have intensified over the last two to three centuries. The United Nations Convention to Combat Desertification (UNCCD) estimates that we are losing 75 million tonnes of topsoil every year and, in India it is estimated that we are losing some 16.8 tonnes per hectare per year. The problem is further complicated over the last 70 years due to the use of biocides. This has negated the possibilities of rebuilding the soil organic matter and there are also the problems of climate change. So, in Andhra Pradesh we tried to see if farming can be the solution rather than problem – that is, if farming can be done in such a way that it rebuilds the soil and helps in improving farmers' livelihoods and citizen's health. We believe that natural farming has this potential.

One breakthrough that we have achieved is that we are able to harness water present in the air. We tried this experiment two years ago with 11 young agriculture graduates and this year more than 90 000 farmers across the state are practicing it, although we are still in the process of studying it.

In the last five years of this journey, we found that there are universal principles of natural farming or regenerative agriculture which are applicable in India as well as outside India. The key issue is that the soil biology has been diminished over the last several decades of use of biocides and other practices. The attempt through natural farming is to trigger the soil biota to come back to its original form, involving the use of bio-stimulants as the catalyst, increase in organic residues (especially the crop residues), use of indigenous seed and pest management and better agronomic practices.

The second breakthrough that we have achieved is natural farming plus pre-monsoon dry sowing, which has a lot of answers for dryland agriculture.

In 2016 we started with around 700 villages and 40 000 farmers. Last year (2019) we had covered close to 700,000 farmers of which 4.5 lakhs farmers had farmlands and there were 250 000 landless farm workers. So, it is about 17 times scaling up in four years. This year we plan to take this to 10 50 000 (10.5 lakh) farmers so we'll be present in about one third of the villages of the state.

The APCNF system achieves significant cost reduction for most of the important crops. Just by eliminating chemical fertilizers and pesticides we have been able to achieve very significant cost reductions and therefore the net income increases. We can see an increase of INR 20 000 per hectare for paddy, 10 000 for maize, 25 000 for Bengal gram, 24 000 for cotton and Bengal black gram.

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Our attempt is that APCNF can protect jobs in agriculture so that young people in the villages can get decent incomes ranging from INR 10 000 to 25 000 per month. We hope by the end of 2020 to have around one to two thousand models that can then become the plots we can use for training youth in profitable employment within the village. This is of great interest to us, especially given the current context of COVID-19, due to which many young people have returned to the villages.

What are the challenges in the adoption of APCNF by more farmers? The biggest challenge is the mindset because farmers, and all of us, have been addicted to chemicals so we're not able to think that farming can be done without chemicals. The second is communicating the appropriate knowledge to the farmers, which we are trying to address through videos, flip charts and other material. While we have borrowed heavily from Mr Palekar, we decided that we should not be confined to only one school of thought.

The scaling up of APCNF in the state has happened through women's self-help groups (SHGs). These SHGs are perhaps the most important platform for this programme. Women's SHGs started in Andhra Pradesh about 20 years ago and cover almost 90 percent of rural women, with federations at the village level, mandal (block) level and the district level. We have spent a lot of time and effort in building the capabilities of these SHGs in managing their collectives, with their livelihoods, dairy, marketing, bank linkages, their interface with the government, etc. The women's SHGs provide critical support to members in the process of transition to APCNF and collectively help each other. This is a very critical part of how the scaling up has happened in Andhra Pradesh and that's what gives me hope that this can be done in other parts of the country because now the women's SHG system is ubiquitous in virtually all the states.

Another important factor in dissemination is that the knowledge transfer for APCNF is happening through a best practicing farmer, providing hand-holding. But we also decided to have a catalytic force in the form of young agriculture graduates working as natural farming fellows, currently 150, and we plan to expand this number.

Regarding the adoption of APCNF, it is interesting that the small and marginal farmers are the ones who are adopting it first and the medium and large-scale farmers are taking more time. We can divide the adoption of APCNF into several phases. The first five to seven years is the induction phase – a very critical phase during which enrolment happens and farmers start moving into it and start experiencing benefits. In the next phase they themselves build organizations to maintain this. This would be another seven to eight years.

We had estimated about two years ago that the cost for the state to ensure that the transition of all the farmers to APCNF takes place by 2027 is 17 000 crores. But if the entire state moves to national farming it can save around 4000 crores every year on fertilizer subsidy and another 4 000 crores on electricity subsidy. Considering the 8 000 crores savings that it can generate for the government itself the investment is worth it. Apart from this there is the money that the farmers are saving by not using fertilizer and pesticides. And there is water saving which we are not computing and also huge ecosystem benefits. So, this is the most profitable investment for any government in terms of financing the programme even if you don't compute the other benefits.

Name	Ms Saraswati Kommojula
Date	WS02 – 15.10.2020
PPT	No
Synthesis	

(In Telugu, translated by Vijay Kumar)

She is working in Vijaynagaram district, on the millets programme, for many years. She also works with the women SHGs and their experience over the last four or five seasons has been very favourable. The area has rain-fed agriculture and due to vagaries of monsoon the farmer's life had become very risky and many of them gave up farming and took up the MGNREGS work or migrated to urban areas. Farming had become a burden with little certainty of assured income.

Prior to introduction of the millets and the pre-monsoon dry sowing they would take only one crop and even that crop was not assured. Now they have divided the year into three windows. The main crop is paddy, based on tank irrigation. Their experience is they do not have to add anything except the labour cost and a little bit of bio inoculation. Consequently, the cost of cultivation has declined very significantly and the productivity of the crop is also very high. Thanks to crop diversity they are all eating healthy food, including green leafy vegetables. The third crop can be either millets or pulses while some farmers opt for vegetables. The important point is that farmers are involved with their land 365 days of the year and they see a sense of dignity in being engaged with farming. Women as lead farmers are actually providing the momentum for this transformation. Because women are playing a leading role, they are looking at the immunity power of the food that they are producing and are thus contributing to the health of the community.

Name	Mr Tomio Shichiri
Date	WS03 – 26.11.2020
PPT	No
Synthesis	

Tomio Shichiri, FAO, welcomed and congratulated all for the joyful festive season and said that FAO India greatly appreciates the contribution of all the experts for participating in the deliberations of the Expert Group (EG). In the last two workshops we had fruitful discussions on various aspects of agricultural development such as marketing, economic viability, mechanization, processing, certification, large-scale adaptability and policy-related questions. The existing socio-economic model and policy in India has evolved through a process based on evidence, experimentation and ground truths. However, there is great diversity in India and one size cannot fit all. Local biodiversity and cultural aspects are very important. Going forward, we need to evolve holistic solutions based on systems thinking and keeping in mind the needs of small farmers.

In the last two workshops Vijay Kumar ji of RySS, Bruno of CIRAD and Anne-Sophie of FAO HQ edified us with the process of scenario building and the objectives of this study. We look forward to more in-depth discussions and active participation of the EG members today and in subsequent workshops. The COVID-19 situation permitting, we hope to have the physical workshop in the first quarter of next year, which should provide an exciting opportunity for networking and exchange of ideas.

Name	Ms Anne-Sophie Poisot
Date	WS03 – 26.11.2020
PPT	Yes
Synthesis	

Anne-Sophie presented a recap of virtual workshop 2. She presented the APCNF programme at a glance and reiterated the characteristics, advantages and achievements of the APCNF work in AP, including higher yields, greater income, harnessing water from the air, climate change resilience, improved biodiversity, youth employment, etc. She concluded with pertinent questions about the future of natural farming – questions about scientific evidence and data, subsidies, markets, scalability and the way forward.

Name	Mr Rakesh Kapoor
Date	WS03 – 26.11.2020
PPT	Yes
Synthesis	

Rakesh presented an introduction to the perspective of futures studies (FS) and foresight – the former is the more analytical and academic study of the future while foresight is considered more action-oriented. He introduced some of the key concepts of FS, gave an outline of the history and origins of the subject and shared the present scenario of the discipline (courses, organizations, books and journals) – both globally and in India. Rakesh shared some examples of foresight activities, agencies and studies done in India as well as Andhra Pradesh. Since FS and foresight are not very well known in India, one important purpose of this presentation was to make the EG members familiar with the futures perspective, some examples of studies and tools such as scenario building, so that we can make use of these tools in the AGroEco2050 study.

Name	Dr Bruno Dorin
Date	WS03 – 26.11.2020
PPT	Yes
Synthesis	

The starting (complex) question of the Agribiom model is: How to help farm nature and feed humanity in a (much more) sustainable way? The model is meant for a heterogeneous audience...economists & non-economists, data-fan & data-averse people, macro- and micro experts, academics and non-academics, policymakers & non-policymakers, farmers & non-farmers, etc. The usual expectation from the audience with regard to a model is a "press button model" which, after complex calculations, tells you what is the best solution. In Agribiom, on the other hand:

- There is no such "button", no "optimization", etc.
- Agribiom is a "learning machine", and not "machine learning" (the opposite!)
- It is "based on an analytical framework and a set of assumptions (the assumptions of the audience or participants in the study) that condition its results" (Dorin and Joly, 2020)
- "What comes first is societal choice, then modelling to express it and analyse the consistency and plausibility of the scenarios" (Dorin and Joly, 2020)

Bruno stated that all models are tools of government: Dorin and Joly (2020) argue that "All models are partial representations of reality; their results depend on analytical frameworks and a set of assumptions." Economic models are hybrid, both tools of evidence and tools of government. They are tools of evidence, hence "truth machines", but also tools of government, with a multi-faceted political dimension. "In doing so, these models make invisible key actors (e.g. small farmers) or alternative technologies (e.g. plant-plant and plant-animal biological synergies)." The Agribiom model is designed to favour democratic learning, not prediction and prescription. "What matters is not 'speaking truth to power' (the traditional positivist stance) but, instead, opening up the debate and fostering democratic learning and action."

Three basic conditions are required to be met for the model to be a "learning machine"

i. the model has to be flexible enough to allow the exploration of both historical pathways and very different future trajectories, including normative scenarios;

ii. the model has to privilege simplicity and comprehensiveness, thus aggregated virtualities (regions, products, processes...) instead of detailed but selective sub-models that do not better capture the complexity and potentiality of the real world, or even reduce the representation of the latter;

iii. the model has to be transparent through an interface that makes it understandable and accessible to a wide range of stakeholders.

When these conditions are met, the model can become a "tool for exploring alternative trajectories collectively, constructing desired futures, testing consistency and identifying critical points". Thus, the Agribiom model is a quantitative tool designed for exploring past and future production, consumption & trade of biomasses through collective expertise & debates. The main engine of the model is built on the biophysical resources (R)/ Uses (U) balances (BRUB). Bruno shared the summary of assumptions and results when applying this model to the world, using the Agrimonde GO trend scenario and the Agrimonde 1 normative scenario.

In the second part of his presentation Bruno highlighted the challenges for developing the Agribiom-India model. These include connecting the "Agribiom Lewisian Model" with Agribiom main engine (BRUB) in order to deal with the country's main problematic (employment, farmers' incomes, land productivity); building an interface of Agribiom-India in R-Shiny (in parallel to Microsoft Access) for online use and sharing and map drawing; compiling historical data on land use, human and animal populations, consumption, production, trade; building a new "Agribiom Livestock Model"; estimating annual "commodity balances" (as FAO has done for India as a whole and other countries); and integrating new indicators such as crop diversity index, GHG emissions from crops/ livestock, fertilizer and energy consumptions, public subsidies, and virtual water consumption. He shared some specific details of these challenges and shared some of the dashboards of the model based on assumptions about GDP growth, labour productivity, workforce and income gap between agriculture and non-agriculture sectors.

Name	Ms Anne-Sophie Poisot
Date	WS04 – 24.02.2021
PPT	Yes
Synthesis	

Anne-Sophie presented a recap of the presentations made and ideas shared during the previous virtual workshop, WS03. PPT of her recap is available on Google drive.

Name	Mr Pavan Sukhdev and Mr Nachiketa Das
Date	WS04 – 24.02.2021
PPT	Yes
Synthesis	

The TEEBAgriFood initiative aimed to provide a comprehensive economic evaluation of the "eco-agri-food systems" complex, and to demonstrate that the economic environment in which farmers operate is distorted by significant externalities and a lack of awareness of dependency on natural, human and social capital. It is based on the fundamental belief that you cannot manage what you do not measure.

It examines Stocks (the capital base of production), Flows through the value chain, Outcomes (changes in the capital base) and Impacts (contributions to human well-being). The Contributions to Human Well-Being' parameter is measured in terms of the creation of four kinds of capital stocks: natural capital, produced capital, human capital and social capital. Human Capital includes livelihoods, skills, nutrition, working conditions and occupational health). Social Capital includes social networks, land access/tenure, increased employment opportunities, food security, institutional strengths, laws and regulation, opportunities for community empowerment; cultural knowledge and participation. The variables used for estimating "Produced Capital" are: incomes from agricultural production and processing, distribution, marketing and retail, household consumption, investment in fixed assets such as roads, equipment and machinery. "Natural Capital" is measured in terms of biomass and biodiversity growth, habitat quality, nutrient cycling, ecosystem restoration, reduced Greenhouse Gas emissions and pollutions, agricultural and food waste, wastewater, solid waste and other residuals.

TEEBAgriFood methodology has been applied for the Andhra Pradesh CMNF study, and the study on comparison of open-field stubble burning and the use of technology (i.e. happy seeders) in the Wheat Value Chain in Northern India. The latter investigation indicated better production and reduced health costs due to low air pollution. TEEBAgriFood methodology has also been used in the study of cocoa and coffee agroforestry in Ghana and Ethiopia.

Name	Prof. Srijit Mishra
Date	WS04 – 24.02.2021
PPT	Yes
Synthesis	

In the pursuit of identifying the possible futures scenarios for Indian agriculture, several alternatives are examined to find their efficacies and prospects to address weather-induced or other unavoidable crop loss in the fourth year after three years of normal bounties These futures are compared over a four-year period by examining if cumulative savings at the end of the third year is good enough to meet input cost and consumption needs in the fourth year that is associated with no output. From the six alternatives, the two contrasting futures are an extension of the Input-Intensive Industrial Agriculture, and Knowledge-Centric Sustainable Production with Responsible Consumption where the former falls short of meeting the household consumption needs in the fourth year while the latter after meeting the consumptions needs still has some savings left. Some features of the knowledge-centric futures that is similar to natural farming initiative of Andhra Pradesh are that input and output are interdependent (not input-intensive), that the production is based on a complex system that is diverse and location specific where mixed and multiple cropping is encouraged (as against a single product system based on mono-cropping), that the focus is on reducing risks including by using marginal lands (not enhancing production/yield), that commons are important (as against an increasing reliance on private property), and that it requires community participation (as against subsidies). To realize the knowledge-centric futures it is also necessary that disciplinary silos are broken down, that there is a coming together of modern science with traditional knowledge, and that academia, government, civil society, farmers and non-farmers need to come together in a mutually beneficial and sustainable way.

Name	Mr Arabinda Kumar Padhee
Date	WS04 – 24.02.2021
PPT	Yes
Synthesis	

This presentation brings forth the utterly serious impact of the COVID-19 pandemic such as an alarming increase in the number of undernourished people and under nutrition and stunted children. Padhee argues that The Planetary goal of Zero Hunger is possible only when India achieves its share in the SDGs. He discusses two assumptions concerning the paths Indian agriculture may follow in future. Under the first assumption of continuing conducive policy space, the author highlights several policies and programme interventions. These include a shift of focus of agri-research from productivity enhancement to nutrition, promotion of natural farming, National Food Security Mission (NFSM) on pulses and nutri-cereals, Eat-Right and other Campaigns, and focus on climate resilience. The elements of the second assumption about the changing consumer behaviour are the growing interest of health-conscious people in traditional staples and high-value agricultural products.

Pathways to improve agriculture-nutrition linkage include repurposing public policies towards food systems transformation: crop diversification; strengthening sustainable value chains: increased participation of private sector; investing in research and innovation; empowerment of women in agriculture through access to land and decision making; and focus on governance issues.

Name	Dr Y. V. Malla Reddy
Date	WS04 – 24.02.2021
PPT	Yes
Synthesis	

The author attempts to establish a link between two thematic areas of ‘Economy and People’s lifestyle’ and “Agriculture and Farmers” in the context of two futuristic scenarios – ‘Business as Usual Scenario-2050’; and ‘Agro-Ecology Scenario-2050’. In the “Business As usual Scenario”, ‘the Economy and People’s Lifestyle’ will be characterized by peaked and never-ending materialism and consumerism; and subhuman living conditions and human suffering. Correspondingly, Indian agriculture will exhibit the following developments: big loss of large farming population; widespread corporate farming (including robotic); weak food security governed by western food culture; outbreaks of pests and endemic diseases, highly degraded soils and ecology and polluted environment; climate change pandemic destroying agriculture; and the farmers in distress abandoning farming.

The author forecasts that in the “Agro-Ecology Scenario-2050”, the imagery of the “Economy and People’s Lifestyle” will consist of people pursuing life with a sense of purpose; simple living with fashion replaced by oriental lifestyle; widespread pursuit of conserving nature; decentralized informal production entities; social justice and ethics governing society. In this scenario, 60 percent of people live on agriculture with farming becoming a preferred occupation, and small-holdings becoming viable with integrated farming. There will be high agro-biodiversity; no poverty and distress and migration; followed by complete mitigation of climate change pandemic.

Name	Dr Richa Kumar
Date	WS04 – 24.02.2021
PPT	No
Synthesis	

To think about the future, Richa Kumar did not present any future scenarios, but invited us to go back to the past and wonder if the Green Revolution (GR) was really necessary. The narrative/rationale at that time was a direct relation between growing population and availability of food, and the risk of famine or hunger that happened in the past (e.g. "the colonial famine of 1943"). But A. Sen taught us that famines are much more a matter of local access rather than of food availability at the national level. Moreover, the GR was launched in a very specific political context:

- The food aid PL480 to India was a way for the United States to export its agricultural surpluses and stabilize domestic politics, and made Indian urban consumers dependent upon PL480.
- The United States Marshal Plan elsewhere was a way to develop markets on specific products in "allied countries" and to fight against the Soviet, Chinese and Vietnamese regimes or their expansion.
- No markets were developed/encouraged in India for products such as millets. All in all, there were good historical reasons to develop the GR in India, but it was not a matter of low/insufficient food production in the country!

Name	Ms Anne-Sophie Poisot
Date	WS05 – 27.04.2021
PPT	Yes
Synthesis	

Anne-Sophie presented a recap of the presentations made and ideas shared during the previous virtual workshop, WS04. PPT of her recap is available on Google drive.

Name	Mr Rakesh Kapoor
Date	WS05 – 27.04.2021
PPT	Yes
Synthesis	

Rakesh made a presentation on Andhra Pradesh 2050: Elements Towards Two Scenarios. He presented the main elements or "storylines" of the two scenarios, Industrial Agriculture and Natural Farming, envisioned for Andhra Pradesh 2050. The elements in these two scenarios are based on various discussions/papers/presentations on natural farming/agroecology and on industrial/conventional agriculture, and on presentations by group members so far (Vijay Kumar, Bruno Dorin, Pavan Sukhdev, Anne-Sophie Poisot, Srijit Mishra, Arvind Padhee, Malla Reddy, Richa Kumar, Subhash Garg, Rakesh Kapoor) and on various inputs received from Expert Group members during previous workshops.

The presentation flagged some statements that may be contentious and may require debate. Also, Rakesh emphasized that on some of the quantitative aspects, more precise assumptions and models will be discussed in the forthcoming physical workshop, including with the help of the Agribiom model/dashboard. He requested all EG members to give their feedback and suggestions on the two scenarios so that the scenarios could be refined for the purpose of this study.

Name	Mr Subhash Garg
Date	WS05 – 27.04.2021
PPT	No PPT, Word file
Synthesis	

Agriculture prior to industrialization was predominantly natural agriculture.

Industrialization brought three major changes to agriculture – mechanization of agriculture processes, chemicalization of inputs and introduction of digitalization of quite a few agriculture practices.

Industrialization of Indian agriculture, which is behind a few decades compared to the west, has helped India solve food shortage and generated steady growth, but improper and unwise industrialization – excessive use of urea and pesticides, for example, has brought many negative side-effects making the quality of agriculture produce suffer.

The natural agriculture experiment initiated in the State of Andhra Pradesh is finding excellent natural alternatives to resolve problems caused by excessive chemicalization, but has not been very innovative in the use of mechanization and digitalization, which are necessary for its greater success. In this experiment, the small and marginal farmers are adopting natural farming in the rain deficit districts of the state. The produce is found wholesome and good in nutrient quality and content. However, the author argues that reliable data is necessary to validate the efficacy of this initiative in terms of increased income and productivity in comparison with those farmers who are engaged in industrial agriculture.

There are three broad choices for the Indian policymakers- first, continue with present industrialization push model with some experiments of organic, natural and other agroecological agriculture, pursue a mixed approach providing a major thrust to natural agriculture experiment to catch up and third, to switch to a completely income support-based approach without any subsidy support for inputs, which introduces complete freedom to farmers under rigour of market discipline.

For the realization of the 2050 Indian agriculture objectives, it would be best to go for a well-built direct income support scenario that will protect farmers' incomes, save costs and raise productivity (the third policy choice).

Two major policy reforms are suggested for the realization of the above scenario: single income support for farmers, delivered on per acre basis, transferring this amount to farmers' accounts; and complete removal of all the restrictive laws such as ceiling laws, leasing laws and privatizing all the input subsidy programmes. It would also be necessary for the government to dismantle the MSP programme and make procurements for the food security programme from the market.

Name	Mr Ajay Vir Jakhar
Date	WS05 – 27.04.2021
PPT	No
Synthesis	

Things will not see much change from the present scenario unless there are major improvements in governance. First, regarding finances. I think the central government today is literally bankrupt as are other state governments and not only because of the extent of the borrowing but the inability to raise resources in future have been exaggerated by COVID-19 and this limits the capacity of the government to do what it wants to do and it will have to make compromises. In this scenario, agriculture production and farming will be the first thing that will get hit.

Second, the political economy always favours consumers. Not only because the urban population is increasing in number but because the percentage of the total population will substantially also increase.

Third, we are spending possibly 0.2 percent of the agriculture GDP on research. It should at least go up to 1 percent. We have 50 percent vacancy in all levels in agriculture research and extension services. Also, the research will stay focused on monoculture cropping patterns with the occasional breakthroughs and productivity per unit for one crop or the other. Research on agriculture economics is also neglected.

Fourth, multinational consulting firms and private philanthropies are influencing India as they are influencing policies all over the world. The establishment is not better equipped to make independent decisions and that's why they will become dependent on these consulting firms and philanthropies, which is not good for the national Interest. Many conferences on food and food systems, not only across the world but also in India, do not have a single panellist or a speaker who represents practicing farmers.

Fifth, we can expect greater consolidation of power and money. A few players in packaged food retail, agriculture and technology and e-commerce – in each of these segments - will have tremendous power over organized food consumption supply and production.

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Sixth, our biggest problems will remain availability of water and quality of soils. In the next 20-30 years we can easily expect that at least cropping intensity will decrease on 10 to 15 percent of the land because of water issues. We will not be able to value and have investments come to things like payment for farm ecosystem services and things like that unless a good measurement matrix is developed.

Population will stabilize in 20 years and demand for everything other than cereals will go up. We can meet this demand only if we can focus on water use and soils sufficiently well enough. The population in agriculture as a percentage will reduce to something like 30 percent because there are no other alternative opportunities.

Seventh, MSP procurement is here to stay for a few staple crops, maybe a few crops will get added to it. But open-ended procurement will come to an end and will be limited to five-acre farmers wherever it happens.

Eighth, free electricity is on its way out, not because political leadership does not want to provide it, but because the state finances will not allow it after two to three years after GST compensation comes to an end. There's no way free electricity money can be allocated.

Ninth, food wastage is going to increase substantially and food safety will be a major issue. Food exports from India in the future will depend upon pesticide regulation, which should be transferred to Environmental or Health Ministry departments. If it stays with agriculture. It will impact high value food produce exports from India because nobody is going to buy low quality produce.

Lastly, the government's approach is and will be a minimalistic intervention. PM Kisan is an example of this. They give you some money per month. It is obviously not enough for you to survive, but they think it is enough for you to tide over your problems.

Name	Dr Ranjit Kumar
Date	WS05 – 27.04.2021
PPT	Yes
Synthesis	

The author analyses two possible scenarios for Indian Agriculture 2050: the "Business as Usual" and the "Agro-ecologically Optimistic Scenario". According to him, the first will be characterized by an absence of specific policy to promote natural farming (NF), continuing of fertilizer and other subsidies and the reluctance of the ICAR/SAU system to subscribe to the NF practices. The outcome of this scenario will be the indifference of farmers towards NF and a high increase in the adoption of new varieties, technologies and chemicals. Its main fallouts will be overexploitation of groundwater, serious soil pollution, big health hazard burden and ever-increasing subsidy burden.

The author builds a highly promising Agro-ecologically Optimistic Scenario on several futuristic policies/actions. These include a compensation policy for the NF farmers; the ICAR/SAUs providing the best research support; and incentivization of green zones in the country. His projections of the outcomes of this scenario are improved soil health, high groundwater savings, and chemical-free food; reduced input subsidy burden; and farming becoming profitable and less laborious with a high resilience towards climate change. The author predicts that this scenario will be driven by a new generation of educated and technology-savvy farmers, increased cropping intensity and use of micro-irrigation and custom hiring services, coming up of agro-tech startups and better safety nets for farmers through the Farmer Producer Organizations (FPOs).

Name	Prof. Gopalsamy Poyyamoli
Date	WS05 – 27.04.2021
PPT	No PPT, Word file
Synthesis	

The author argues that India's agricultural production base is characterized by three very compelling disconnects: agriculture and the environment – producers and consumers, policies and expectations. He brings forth the social ecology of the country's food system in terms of several factors such as the issues of soil health and plant nutrients, high climate change vulnerability and the risks of GM foods among others. In this context, he proposes that the country needs to adopt what he calls as the "agro-ecological transitions (AE) system" to safeguard its food system from the impending post-pandemic crisis. According to him, the AE system envisages appropriate eco-technical interventions/innovations and political intention to bring about a socio-ecologically desirable change in Indian agriculture. This system will be based on the agricultural practices and social movements that will promote a climate-resilient inclusive and sustainable food and nutrition system. It will be characterized by a resilient and diverse production style (including rare traditional crops), internally generated and recycled inputs and nutrients, and management of market supply chains. This system will require a complete redesign as a fully community-based entity, driven by the AE cooperatives to be managed by the Farmers Producers Organizations (FPOs) in various parts of the country. These FPOs will also act as co-researchers and as co-facilitators of knowledge with the scientists and play a vital role in investigating the scientific validation of the proposed AE System and its sustainability.

Name	Prof. Rajeswari S. Raina
Date	WS05 – 27.04.2021
PPT	Yes
Synthesis	

The multifunctional and equitable agriculture in a rainbow economy can be considered to consist of three interlinked actions/processes: Local territorial identities, decentralized, deliberative processes; life science-based decomposability/ global value chains; and substantive agro-ecological knowledge-based bio-economy. For the realization of the Agroecology 2050 Scenario, it is necessary to adopt a policy goal of a 4 percent growth rate that should include the goal of minimizing the nutritional inequalities among the people, irrespective of their money incomes and their urban or rural residence. For a national policy for decentralizing food, agriculture and nutrition, there is a need to take full account of local resources, availabilities, costs, preferences and traditions. The Innovation in-and-for agriculture should include intensive agroecological alternatives (that provide high productivity per ha and per worker); labour using high biological-synergy technologies (organic farming, agroecological production systems, etc.); high value-added per worker; high public investments (to replace subsidies); and policy instruments that foster decentralized innovation capacities. There is an urgent need to mobilize, build and follow new actors, structures and rules and generate both scientific and emotional (political) support for this grand change.

Name	Dr G. V. Ramanjaneyulu
Date	WS05 – 27.04.2021
PPT	No
Synthesis	

In his presentation, Ramoo said any 2030 future scenario must focus on the livelihood security of small and marginal farmers and sustainability of ecological agriculture. He said that even after a percentage drop in the number of farmers, the absolute number of farmers will remain almost the same and a large proportion of these will continue to be small and marginal. Two, many of the success stories on natural farming today pertain to big farmers and there needs to be a sustainable policy framework for small and marginal farmers to transit to ecological agriculture.

Ramoo pointed to three key areas that require attention for a more conducive framework of natural farming for small and marginal farmers.

The first is the creation of a strong and attractive overarching narrative on ecologically sustainable agriculture with which people could then identify. Ramoo referred to the need to resolve 'internal' identity-based conflicts with different forms of ecological farming like natural farming and organic farming and then to pit these as a contrast to conventional agriculture. Ramoo included 'technological sustainability' as part of conventional agriculture. He said the reason for slow traction of ecological farming was related to the internal identify crisis. For example, many people thought some of these forms of farming meant 'going back' to traditional forms of farming whereas farmers themselves are wanting to move away from many of the traditional farming practices.

The second key requirement is to have a coherent transition policy framework which includes more equitable distribution of resources, decentralized governance and management systems. Ramoo referred to their multi-State study on farm subsidies which reveals that maximum subsidy goes to just two to three States and the entire subsidy is on power and fertilizers. States cannot make a transition to ecological farming on their own without changes in government policies. Ramoo recommends community-managed (farmers' producers' companies, women's groups, etc.) systems for ecological farming where farmers can make choices on more sustainable production systems and product-based subsidies. This will feed into the overarching narrative that farmers know what is right and they make the right choices. This also means that current government investments and distribution of financial resources must transit towards more sustainable production systems. For example, after a large financial outlay as chemical fertilizer subsidy farmers cannot be expected to transit to organic agriculture on their own.

Thirdly, on government policies, Ramoo also suggested prioritizing value supply chain to help small and marginal farmers earn better incomes. This is because there are limits to how much productivity is possible from small pieces of land and selling the land would also not be a viable option to promote sustainable livelihood in ecological farming.

Name	Dr A. Ravindra
Date	WS05 – 27.04.2021
PPT	Yes
Synthesis	

The author presents a forecast model of the country's agriculture if it remains caught in its current strides. According to this model, agricultural labour will be scarcer and with high mobility. It will cost more but remain largely casual to the technical aspects of work. Farming will be intensive, coexisting with large export-oriented farms and big livestock farms. There will be a rapid increase in degraded lands. Land ownership will be in the hands of the urban rich more as an asset. The capital will also be urban elite controlled. Water no more will be tied to the land as it will become a high-value commodity. The markets will serve local service economies and deal in higher-value products with access to global niche markets.

To avoid the above highly pessimistic scenario, the author offers a route to healthy and equitable growth of Indian agriculture. He proposes building circular economies-ecologies-food systems to re-configure various support systems in the economy and reorienting technologies to meet the needs of diversity, including the development of high-tech bio-systems. It is also deemed necessary that the new system must have the capabilities to take care of politics around the public investment/incentives realignments.

Name	Ms Anne-Sophie Poisot
Date	WS06 – 24.05.2021
PPT	No
Synthesis	

Anne-Sophie presented a recap of the presentations made and ideas shared during the previous virtual workshop, WS05. PPT of her recap is available on the Google drive.

Name	Dr Fergus Sinclair
Date	WS06 – 24.05.2021
PPT	Yes
Synthesis	

This presentation gives a holistic framework for agroecology as a dynamic concept that involves an expansion from field and farm to the whole food system, and represents a set of practices such as harnessing ecological processes in agricultural production - generic principles, applied locally and driven by a transdisciplinary science. It involves social and political movements that assert collective rights for smallholder farmers and advocate diversity in agriculture and food systems. This way, agroecological and other innovative approaches build sustainable agriculture and food systems (SFS) that enhance food security and nutrition (FSN).

Therefore, a major transformation of food systems requires innovations that support challenging the status quo, involving changes to rules, institutions and practices. In the framework of agroecology, approaches are well articulated and widely practiced sets of principles and methods intended to foster the transition towards sustainable food systems (SFS) for food security and nutrition (FSN), within an overarching vision for the future.

The Transformative Partnership Platform (TPP) on agroecological approaches to build the resilience of livelihoods and landscapes works to address key knowledge and implementation gaps to support agroecological transitions. The 13 basic principles of agroecology include: recycling, input reduction, enhancing soil health, animal health, safeguard and enhance biodiversity, synergy, economic diversification, co-creation of knowledge, social values and diets, fairness, connectivity between producers and consumers, land and natural resource governance and participation of all to support decentralized governance and local adaptive management.

The key recommendations are to promote agroecological and other innovative approaches in an integrated way to foster the transformation of food systems, support transitions to diversified and resilient food systems, strengthen the research support and reconfigure knowledge generation and sharing to foster co-learning, strengthen agency and stakeholder engagement, empower vulnerable and marginalized groups and address power; and use comprehensive performance monitoring frameworks for food systems to reduce inequalities in these systems.

Name	Ms Kavitha Kuruganti
Date	WS06 – 24.05.2021
PPT	Yes
Synthesis	

This presentation attempts to build an "ideal" 2050 scenario for agriculture and rural revitalization for the state of Andhra Pradesh. It puts forth some necessary changes for the materialization of the Foresight Scenario, including the adoption of natural farming as the main pathway. Changes are also required in the legal instruments of procurement, payment for ecosystem services, investments on farmer collectives and extension of financial inclusion of insurance etc. to them. Also, agro-diversity is understood and practiced so that 365 days' green cover is maintained by all farmers and productive resources conserved, improved and managed by communities.

The concept of "technology' will be re-defined by 2050. It will be simple practices with local innovations so that agriculture will be "practices"-led (agronomy) and microbiology led, and not by the conventional content of agricultural sciences, or technologies. Drudgery reduction will be a key focus of technology development. The scenario envisages that agriculture will become a viable 'enterprise' for millions by 2050. Women will have leadership roles in various sectors, and will also have at least half the land owned in their names.

The proposed scenario will create a host of employment opportunities in the natural food industry, soil testing lab services and other input testing services, IT and services sector units set up under the MSMEs, handicrafts, especially organic handlooms, naturopathy-based healthcare services and eco-tourism.

The Anna Swaraj envisaged in AP in 2050 will address justice and equity issues, with sustainable growth, aiming explicitly for the well-being of all. Agriculture will be the main vehicle for tackling climate change emergency with renewable energy sources fully tapped. The government will adopt the 'Happiness and Well Being Index' as the official measure of 'development and progress' in Andhra Pradesh.

Name	Prof. C. Shambu Prasad
Date	WS06 – 24.05.2021
PPT	Yes
Synthesis	

This presentation, in the context of the success of the Green Revolution, argues that the key factors that led to this success are absent for the acceptance and spread of agroecology in the country. It points out that there is a need for newer institutional arrangements such as Innovation Platforms dedicated to scaling up agroecology.

Prasad opines that there should be a rethinking not just on technologies and production processes, but engaging society as a whole by developing shared visions and promoting inclusive, participatory governance. Change is not incremental, sustainability transitions are long-term, society-wide processes depend critically on the emergence and spread of diverse forms of innovation that trigger alternative ways of thinking and living - new social practices, technologies, business models, nature-based solutions.

The paper calls for seeding a new knowledge movement through designing new architectures for rooting diversity of practices and create opportunities for mainstream to 'unlearn'. Researchers are not to be 'centres of excellence' but 'facilitators of innovation'. For creating equitable livelihoods and food systems, it suggests a three-pronged strategy: Build agency- build consciousness, confidence, self-esteem and aspirations); Change relations- The power relations through which people live their lives through intimate relations and social networks (non-formal sphere) and group membership and activism, and citizen and market negotiations (formal sphere); and Transform structures- to overcome discriminatory social norms, customs, values and exclusionary practices (non-formal sphere) and laws, policies, procedures and services.

Name	Mr Tomio Shichiri
Date	WS07 – 29.06.2021
PPT	No
Synthesis	

Welcoming Vijay Kumar ji, Dr Ashok Dalwai and members of the Expert Group, Tomio said that It is a pleasure to see all at this seventh virtual workshop of the AgroEco2050 Foresight Study. The first virtual workshop was held in September 2020 and despite the challenge of the COVID-19 pandemic, we have come a long way and have held six virtual workshops in the last ten months. The COVID-19 pandemic has also highlighted for all of us the importance of the food and agriculture sectors of the economy and rural livelihoods. It has once again made us realize the importance of sustainable agricultural systems and of the health impacts of food and nutrition.

India's diversity of farming systems is impressive, and we have to see the pioneering work on natural farming in Andhra Pradesh and elsewhere in India in the context of this great diversity.

During the past six workshops we have covered the plan and design of the study, the details of the natural farming work being done in Andhra Pradesh by the RySS led by Vijay Kumar ji, the basic principles of agroecology, the views of different expert group members, including various international and national experts and stakeholders. The first draft of the elements for the two scenarios for Andhra Pradesh 2050 has also been prepared and shared with the Expert Group members. The credit for this progress, despite the COVID-19 situation, goes to our Expert Group members, Shri Vijay Kumar ji, Dr Bruno Dorin and our colleagues from FAO.

Today we have the privilege to listen to the views and understand the vision of Dr Ashok Dalwai, who has chaired the government of India committee on doubling of farmers' income that has authored a seminal 14 volume report on this subject.

Tomio thanked Dr Dalwai for sparing time for us today and thanked each and every member of the Expert Group and the project team for their dedication and commitment to carrying out this pioneering study.

Name	Ms Anne-Sophie Poisot
Date	WS07 – 29.06.2021
PPT	Yes
Synthesis	

Anne-Sophie presented a recap of the presentations made and ideas shared during the previous virtual workshop, WS06. PPT of her recap is available on the Google drive.

Name	Dr Ashok Dalwai
Date	WS07 – 29.06.2021
PPT	No
Synthesis	

Though India's population dependent on agriculture has been declining (from 85 percent in 1951 to 48 percent today), the agriculture sector will continue to be a very important employment sector in countries like India which have large populations. This is because absorption of manpower by the industrial and the service sectors will be limited due to the widespread use of emerging technology (e.g. artificial intelligence, big data analytics and satellite-based technology). Thus, by 2050, at least 20 percent, or about 32 crore (320 million) people out of a total estimated population of 160 crore (1.6 billion), will remain directly dependent on agriculture.

India currently witnesses two types of conventional agriculture: the intensively cultivated 'green revolution' agricultural systems practiced primarily in the Indo-Gangetic plains and the irrigated belts of rivers Godavari, Krishna-Kaveri and Narmada; and the 'pre-green revolution' non-agrochemical-based agriculture practiced mostly in the western, eastern and central parts of the country and especially by tribal populations living in forested areas. Green revolution has resulted in marginal rate of returns in the Indo-Gangetic plains and so the government cannot afford to keep paying farmers because they will not be able to gain higher incomes from this. The intense use of agrochemicals has also resulted in loss of soil organic carbon, compromising soil structures, soil texture and soil fertility. The production system now needs to be even more ecologically sustainable with the increasing risks and vulnerabilities associated with climate change. Again, though India has transited from being a food deficit to a food surplus economy, the challenge of achieving

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nutritional security remains and acts as a barrier to harvest the demographic dividend.

Thus, agriculture now has to fulfil three mandates: income, nutritional and ecological security. Adoption of any 'unconventional' or an ecology-based agriculture form needs to be compared and contrasted with conventional agriculture on these three touchstones. Also, non-conventional agriculture may be of different kinds, like organic farming, integrated nutrient management-based agriculture, integrated farming, integrated pest management and precision agriculture. Andhra Pradesh can take the lead in natural farming. The critical need is to have science and national agriculture research systems, comprising the Indian Council of Agriculture Research (ICAR) and the state agriculture universities, to deliver new seeds, new breeds of animals, etc. for the different types of ecology-based farming systems. Apart from science and technology undergoing a paradigm shift, there is a need to have enough data and models to achieve resource use efficiency in these farming systems. For example, if higher incomes will mean a shift to higher animal-based diets than plant-based diets, what would this mean with regard to efficient use of soil-water-animal-fish resources?

From a policy perspective, it is important to see agriculture from an employment rather than an income perspective. Employment that is able to provide sustainable, productive and gainful income to farmers. Thus, the need to consider farmers as entrepreneurs, to use technology and to capacitate them to create agriculture value systems linked to markets. This will rid the sector of under-employment. In addition to primary products, all forms of agro-ecology produce by-products, or 'bio-materials' like straw, the stalk, roots, skin, hair, viscera and bones which can be utilized and generate 'secondary agriculture' employment opportunities, especially in lean agricultural periods. Both primary processing and 'secondary' processing will then create value chains and will be linked to markets. Agro-ecology calls for mixed cropping and diversified agricultural systems and this will contribute to production of 'bio-materials' for industrial use too.

A moot point linked to the above is the aggregation of agricultural produce. How can farmers aggregate small produce and integrate with the market? This could relate to farm mechanization, agri-logistics, storage or processing facilities. With small and fragmented fields, diversified farming and mixed cropping means extra work and drudgery and the new generation does not want to continue working in this mode. So new technologies and business models are required.

Adopting agroecology as a farming system will require income subsidies to support gaps in income rather than input subsidy on 'kinds' of agriculture inputs like water, electricity, seeds, fertilizers and pesticides. Based on some quantification tools, a minimum income threshold will need to be fixed for each farming family who can then be given income subsidy support. The current digital transfers of various entitlements by the government are a good mode for this. Farmers are well informed of market options today and can make rational decisions. Income subsidies will also be more egalitarian because in the current set-up, the kind subsidies benefit only those conventional farmers who have irrigated fields. Rainfed farmers do not benefit from these subsidies because they cannot use these inputs which need more water.

On nutritional security, there is a need to shift from the parameter of crop yield per hectare to nutrients yield per hectare because the change in the nomenclature will refocus on nutritional security of people as well as of farm animals. Another key indicator could also be calories and proteins grown per hectare or per acre of water pond. Thus, production systems will then include horticulture and plantations with agronomic crops. Alternate agricultural technology, whether for organic or natural farming (or any other form of agroecology) should take into account the nutritional requirements of populations in 2030 and 2050 and support agroecological production systems.

In sum, alternate agro-ecological farming systems require new technologies, new science, new business management principles and new policy orientation. The government and the market need to incentivize farmers who are willing toadopt agro-ecological farming systems or other eco-friendly farming practices.

Name	Mr Rakesh Kapoor
Date	WS07 – 29.06.2021
PPT	Yes
Synthesis	

Rakesh made a presentation on the revised draft of the Andhra Pradesh 2050: Elements Towards Two Scenarios. The first draft was presented during WS05. The presentation outlined the main elements or "storylines" of the two scenarios, Industrial Agriculture and Natural Farming, envisioned for Andhra Pradesh 2050. The first draft of this presentation, done during WS05, was based on the various discussions/papers/presentations on natural farming/agroecology and on industrial/conventional agriculture, and on presentations by group members so far (Vijay Kumar, Bruno Dorin, Pavan Sukhdev, Anne-Sophie Poisot, Srijit Mishra, Arvind Padhee, Malla Reddy, Richa Kumar, Subhash Garg, Rakesh Kapoor…) and on various inputs received from Expert Group members during previous workshops. The current revised draft took into account the various comments and suggestions received from the EG members.

The revised draft, too (like the first draft), highlighted that on some of the quantitative aspects, more precise assumptions and models will be discussed in the forthcoming physical workshop, including with the help of the Agribiom model/dashboard.

4.2 AgroEco2050 Anantapur workshop (27/09-01/10/2021)

a) Participants in the Anantapur workshop

First name	Last name	Institution	Position	Email
Tara	BRAGANZA	RySS		braganza.tara@siffindia.org
Debottom	CHAKRABORTY	RySS		chakra.debottom@gmail.com
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Deborah	DUTTA	IRMA	Sr. Research Fellow	deborah@irma.ac.in
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Vattikutti	HARIPRIYA	RySS		
Rakesh	KAPOOR	FAO / Futures Journal (Elsevier)	Foresight Consultant / Editor	mailboxrkapoor@gmail.com
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Krishna	RAO	Kovel Foundation	Chief Executive	raovukanti@gmail.com
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C. P. Nagi	REDDY	RySS	Senior Consultant	cpnreddy@gmail.com
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Tomio	SHICHIRI	FAO	Country Director/ Representative	Tomio.Shichiri@fao.org
M. Mohammad	SOHAIL	RySS		
Yerrakonda	SUDHAKAR	FAO		Sudhakar.Yerrakonda@fao.org

b) Programme of the Anantapur workshop

Overview	Day 1 (27/09/2021) to day 5 (01/10/2021)
Day 0	Arrival in Anantapuram by Sunday evening 26/09 or Monday morning 27/09
Day 1–27 Sep	"Travelling Workshop": field visits to APCNF farms and exchange with farmers
Day 2–28 Sep	Welcome Speeches Introduction to AgroEco2050 study and workshop methodology Retro-prospective on LAND USE (1970–2050)
Day 3–29 Sep	Retro-prospective on POPULATION and EMPLOYMENT (1970–2050)
Day 4–30 Sep	Retro-prospective on GDP and growth rate by sector (1970–2050)
Day 5–1 Oct	First simulations/discussions with the Agribiom Lewisian sub-Model (Lewis Path/Trap in 2050) and revisions of some assumptions if needed (Workshop over by 1.00 p.m. People can depart same day)

Note: From Day 2, meeting gets over at 17.00 hours in order to give participants some free time for their own work.

27/09/2021	Day 1 (field visits)
10:30–19:00	Visits to natural farmers and fields near Veldurthi then Mukthapuram (about 50 km South-Southeast of Anatapuram)

28/09/2021	Day 2 (focused on land use)	
10.00–10.20	Welcome Remarks Welcome Remarks	Tomio Shichiri, FAO Vijay Kumar, RySS- GoAP
10.20–11.00	Introduction to the AgroEco2050 Foresight study and the Physical workshop at Anantapuram EG discussion	Anne-Sophie Poisot, FAO All participants
11.00–11.45	The Agribiom quantitative model: a learning machine for collective foresight Thinking the future of landscapes in 2050 under two scenarios, Natural Farming (NF) and Industrial Agriculture (IA) EG discussion	Bruno Dorin, CIRAD Anne-Sophie Poisot, FAO All participants
11.45–12.00	Tea break	
12.00–13.20	Land Use (Retrospective): - Agribiom dashboard on Land Use and data 1970 to present - Brainstorming - Collective data scanning and discussions on past evolutions in AP and elsewhere	 Bruno Dorin All participants
13.20–14.20	Lunch	
14.20–14.55	Agro-ecological changes in Anantapur since 1960s to Present (2021) – Presentation and Video	Mala Reddy, AF Ecology
14.55–15.10	Presentation on Visioning Exercise done in June 2021 on Natural Farming in India	Prachur Goel, Socratus
15.10–15.30	Andhra Pradesh 2050: Elements Towards Two Scenarios – Second Draft	Rakesh Kapoor, FAO
15.30–16.30	Working groups on Future Scenarios to 2050 (each tries to define questions to be answered, and feed the Agribiom model with assumptions on land use in the two scenarios, with a qualitative story line behind each case)	All participants
16.30–16.45	Tea break	

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16.45–17.45	Reports by working groups on Future Scenarios 2050 Discussion on qualitative scenarios and quantitative assumptions on Land Use in AP for both scenarios for 2050 (These assumptions for 2050 will subsequently be fed into the Agribiom model)	Moderation by Rakesh Kapoor

29/09/2021	**Day 3 (focused on population & employment)**	
09.50–11.15	Summary of working group discussion of previous day on Future of Land Use General discussion and Q&A	Bruno Dorin All participants
11.15–11.30	Tea break	
11.30–11.50	Presentation – "Can Indian Reap the Demographic Dividend?" EG discussion	Rakesh Kapoor
11.50–12.05	Video: The Indian Economy - Next Big Shot? (8 minutes) https://www.youtube.com/watch?v=nWkcyjTgG1k and EG Discussion	All participants
12.05–13.15	Population & Employment (Retrospective): - Agribiom dashboard on Population& Employment, and data 1970 to present - Collective data scanning and discussions on past evolutions in AP and elsewhere	Bruno Dorin All participants
13.15–14.10	Lunch	
14.10–15.20	Population and Employment (Prospective): - Discussion on the future of population in 2050 under two scenarios, Natural Farming (NF) and Industrial Agriculture (IA)?	Bruno Dorin All participants
15.20–16.15	Working groups on Future Scenarios to 2050 (each tries to feed the Agribiom model with assumptions on employment in NF and IA scenarios, with a qualitative story line behind each case)	All participants
16.15–16.30	Tea break	
16.30–17.00	Reports by working groups on Future Scenarios 2050. Discussion on qualitative scenarios and quantitative assumptions on Employment for both scenarios in AP for 2050 (These assumptions for 2050 will subsequently be fed into the Agribiom model)	All participants Moderation by Rakesh Kapoor

30/09/2021	**Day 4 (focussed of GDP and labour income)**	
09.40–12.00	GDP and Labour income (Retrospective): - Agribiom dashboard on GDP and Labour income, and data 1970 to present - EG discussion: Collective data scanning and discussions on past evolutions in AP and elsewhere	Bruno Dorin All participants
12.00–12.15	Tea break	
12.15–12.45	Videos on Future Farming: - KNOW: The Future of farming (4 mn) - Farms of the future (6 mn) - Professor Guy McPherson Asks for Four Minutes of Your Time (4 mn) EG discussion	
12.45–3.30	India Trends 2050 EG Discussion	Rakesh Kapoor All participants
13.30–14.30	Lunch	

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14.30–16.15	Working groups on Natural Farming versus Industrial Agriculture scenarios and Role play on arguments from advocates of both scenarios EG discussion following role play	All participants
16.15–16.30	Tea break	
16.30–17.30	Summary of the assumptions suggested by the EG members for the two scenarios to 2050 EG discussion	Bruno Dorin All participants

Day 5, 1st October

01/10/2021	Day 5	
09.00–11.00	Running of the Agribiom Lewisian Model: - Presentation of the ALM and view of the results for the two scenarios in AP - Discussion and revision of the assumptions (on GDP, Employment, Land Use...) if required	Bruno Dorin All participants
11.00–11.15	Tea break	
11.15–12.30	Finalization of assumptions for different parameters for the two scenarios done and summary recorded on whiteboard. Close of Workshop. Brief closing remarks.	All participants Vijay Kumar
12.30–13.30	Lunch	

4.3 AgroEco2050 Delhi workshop (29-30/11/2022)

a) *Participants in the Delhi workshop*

	First Name	Last Name	Organization	Note
Mr	Shaik	ANWAR	APPI	
Ms	Sangeeta	AGARWAL	KfW	Special guest
Mr	Debottom	CHAKRABORTY	RySS	
Dr	Rajeshwar Singh	CHANDEL	Vice-Chancellor, Dr YS Parmar University of Horticulture and Forestry, Himachal Pradesh	Special guest
Ms	Lakshmi Durga	CHAVA	RySS	
Mr	Ashirbad	DAS	SuATI-Advisor Research & Policy	Special guest
Dr	Bruno	DORIN	CIRAD/CIRED/ CSH	
Mr	Muralidhar	G.	RySS	
Ms	Jimena	GOMEZ	FAO	
Mr	Ashish	GUPTA	Organic Way of Life	
Mr	Rakesh	KAPOOR	FAO	
Dr	Ranjit	KUMAR	NAARM	
Dr	Richa	KUMAR	IIT-Delhi	
Mr	T. Vijay	KUMAR	RySS	
Prof.	Srijit	MISHRA	IGIDR	
Shri	Pari	NAIDU	Jattu Trust	
Ms	Chukki	NANJUNDASWAMY	KRRS	
Ms	Liesa	NIESKENS	Advisor on AE-knowledge exchange	Special guest
Ms	Anne Sophie	POISSOT	FAO	

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Mr	Krishna	RAO	Kovel Foundation	
Mr	C. P. Nagi	REDDY	RySS	
Prof.	D. Narasimha	REDDY	Retd. Chair Prof., NIRD	
Ms	Swati	RENDUCHINTALA	RySS	
Mr	Stephen	SHERWOOD	EkoRural and Groundswell International	Special guest
Mr	Srinivas	MANGIPUDI	Visual Think	Special guest

b) Programme of the Delhi workshop

29/11/2022	**Day 1**	
09.30–10.00	Welcome Remarks Introductions	Vijay Kumar, RySS- GoAP All participants
10.00–10.30	Workshop Objectives & the AgroEco2050 Foresight study so far	Anne-Sophie Poisot, FAO
10.30–11.30	Technical presentation of the qualitative assumptions, the dashboard/model "Agribiom-India" and the main quantitative findings for the two scenarios	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO
11.30–11.45	Tea break	
11.45–12.05	Introduction to the Visual representation process to be done by Srinivas Mangipudi, VisualThink during the workshop	
12.05–13.15	Technical presentation of the qualitative assumptions, the dashboard/model "Agribiom-India" and the main quantitative findings for the two scenarios (cont.) Discussion and Bain-storming	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO All Participants
13.15–14.15	Lunch	
14.15–15.20	Technical presentation of the qualitative assumptions, the dashboard/model "Agribiom-India" and the main quantitative findings for the two scenarios (cont.) Discussion and Bain-storming	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO All Participants
15.20–15.35	Tea break	
15.35–17.30	Thematic Discussions: Population and employment Assumptions (quantitative + qualitative) made for both scenarios during virtual workshops and in Anantapur Discussion and Validation	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO All participants

30/11/2022	**Day 2**	
09.30–10.00	Welcome Remarks Introductions	Vijay Kumar, RySS- GoAP All participants
09.30–11.00	Thematic Discussions: Land Use Assumptions (quantitative + qualitative) made for both scenarios during virtual workshops and in Anantapur Discussion and Validation	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO All participants
11.00–11.15	Tea break	
11.15–13.10	Assumptions (quantitative + qualitative) made for both scenarios during virtual workshops and in Anantapur Discussion and Validation	Bruno Dorin, CIRAD & Anne-Sophie Poisot, FAO All participants
13.10–14.10	Lunch	

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14.10–14.20	Presentation of visuals by Srinivas Mangipudi, VisualThink and discussion	All participants
14.20–16.00	Brainstorming on policy Implications and policy pathways forward: “What would it take for the Agroecology scenario to materialize”? Including on: - Reorienting research and agricultural innovation systems - Governance and institutions - Subsidies - Financing the transition to sustainable food systems versus financing the status quo - Responding to the climate emergency - Capacity development, training and knowledge sharing - Managing conflicting interests of stakeholders - .../...	All participants (moderated by Anne-Sophie Poisot, FAO)
16.00–16.15	Tea Break	
16.15–17.15	Discussion on: - Implications and recommendations - Finalizing summary conclusions and key messages - What next for the Foresight Study: with whom do conclusions need to be shared to have impact? In what form, how, when?	All participants (moderated by Anne-Sophie Poisot, FAO)
17.15–17.30	Presentation of visuals by Srinivas Mangipudi, VisualThink	
17.30–17.50	Workshop Closure	

This book presents the first macroeconomic scenario of a full transition to agroecology in 2050. It is for Andhra Pradesh, a state in southern India with 53 million inhabitants and 9.3 million farmers in 2020. The "Community-managed Natural Farming" scenario is compared to an industrial food and agriculture intensification scenario to assess its performance in various areas such as employment, land use, food production, economic growth or income inequality.

The book also includes a unique compendium of statistics over more than half a century (from the 1960s to 2020), at three geographical scales (World, India and Andhra Pradesh), on the multiple and interconnected dimensions of agri-food systems and their structural transformation.

Overall, the book is a unique presentation of the method and results of a participatory foresight exercise which combines quantitative and qualitative approaches, expertise and knowledge to help societies and their governments to better choose the future world in which they would like to live and work.

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