1 Ecological Thinking and Agricultural Sustainability

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Abstract

Ecological or ecocentric thinking emerges from our appreciation of oneness with nature. Technocentric perception driven by scientific and empirical thinking builds on Charles Darwin's Theory of Evolution and Adam Smith's Wealth of the Nations. Those who can empathize with the ecocentric thinking can see the 'big' picture and understand the illusion of human mastery over nature. Nature has its precise mechanism of constant renewal and replenishment of materials, operating in a cyclical manner. When we humans thought that we have gained mastery over technology, we started interfering with the cycles of nature. Eventually, we damaged them to that extent that we have made them go berserk and turn linear. Consequently, we are currently facing stunning problems, such as pollution and other similar displeasing developments on Earth. In today's highly technocentric environment, where economic paradigms rule the roost, ecological paradigms are seen as 'primitive' and 'conservative'. To a few others, ecological paradigms appear daunting, challenging, and difficult to practice. The term 'sustainable development' refers to something more than, simply, growth. A change in the kind of growth is needed, a kind of development that is less material- and energy-intensive and more equitable in the distribution of its benefits. This emphasizes that changes are necessary and that the security, well-being, and the survival of the planet should be mutualistic with those changes. Sustainable development is not about giving priority to environmental concerns, but it is about incorporating environmental strengths into the economic system. Sustainability represents ideas of stability, equilibrium, and harmony with nature. Sustainable development is an attempt to reduce the politics in decision-making by artificially replacing conflict with consensus. Ecological thinking and its derivative ecological

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agriculture are practices that spin around simplicity and modesty. Aggressive dollar-driven thinking has no place in ecological thinking. Climate change, for example, is a problem created by us humans because of our badly thought-out and hasty practices of land use. If we realize this weakness and remedy it, then we still have hope to leave a cleaner and better world for the future generations of humans as well as other organisms that are as important as *H. sapiens*! We think that speed and rapid turnarounds of events are the norms of today. Is speed the root cause of present-day ecological–environmental malady, which has pushed us to think of sustainability?

Keywords

Agricultural sustainability · Ecological agriculture · Ecological thinking · Organic farming · Biodynamic farming · Natural farming · Permaculture · System of rice intensification

1.1 The Present Agricultural Scene

Over millennia, or perhaps for even more, our human ancestors lived hunting wild animals and gathering wild plants. Somewhere between 4500 and 10,000 years ago, the hunter-gatherer societies, in at least seven regions of the world, independently domesticated specific animal and plant species, which subsequently developed into agricultural economies.

One major human intervention of nature was the establishment of settlements, which involved the disturbance of soil and associated vegetation. Humans cleared vegetation to build residences. As long as humans remained hunter-gatherers, the disturbance to the natural environment was minimal, given the vastness of time. Once they moved to other localities establishing new settlements, the previously occupied sites regenerated back to near-natural near-original state. Such a recovery never eventuated — and could never happen — with humans settling permanently in specific places (Raman 2019). Clearing vegetation for building residences had its own other forms of consequences: The cleared sites encouraged aggressive, invasive plants to colonize and occupy vacant spaces due to either deliberate introductions or natural migrations. When humans moved from one place to another, they carried seeds of certain plants either deliberately or inadvertently and 'introduced' them into newer environments. One recent-time example would be the deliberate introduction of mango trees (*Mangifera indica*, Anacardiaceae) by humans into a new biogeographical locality—West Africa in 1824, from where this plant was spread to other warm regions of the world (Rey et al. 2004). Rivers are one other critical source that distributes seeds and vegetative material propagating them in new environments. Thus various reasons explain colonization of cleared areas by plants that do not usually occur in (or belong to) a particular region. The best examples for the natural colonization of plant material into the Indian landmass are the plant species that were domesticated by early Holocene 'farmers' of the Fertile

Crescent nearly 12,000 years ago. Those introduced plants, later, in 9000–10,000 years ago, stimulated the beginnings of systematic agriculture in southern Asia (Singh et al. 2016).

The transition from a foraging to a farming way of life was a major event in the evolutionary history of humankind. During this period, humans tried various techniques and primitive technology, thus making efforts to achieve better outcomes. Technology played a key role in enhancing agricultural capabilities of humans. The industrial revolution in Europe in the late seventeenth century ushered in new techniques and technologies that changed the global profile of agriculture. Since World War II, some nations have produced grains and other agricultural crops at around two-and-a-half times more than what they really required. Advancing technology and the urge to produce more in that period placed immense pressure on national economies to push agricultural production to greater levels. By responding to this economic pressure — by manipulating land and water to our advantage — we humans have inflicted substantial disruption to functional ecosystems on which the whole fabric of civilization depends. Through such behaviour we have pushed the world to a new, hitherto unperceived crisis. We have placed the Earth and its cycles of natural materials under stress, similar to the way we would strain a truck by simply loading it with 2–3 times more than its recommended load-carrying capacity. Such an action has resulted in what we today simplistically describe as 'environmental problems'. Some examples would be human population increase and consequently changed demographics, air and water pollution, overexploitation and depletion of natural materials such as plants and animals, and accumulation of non-degradable wastes, which turn into toxic over time.

Land came under severe stress in the last few decades (Fig. 1.1) (United Nations Environment Programme 1999). One highly serious issue that arose from unplanned utilization and overstressing of the environment is the widespread and unprecedented rate of recurrence of famines and droughts and eventual impoverishment in many parts of the world (The Brundtland Commission 1987). The Green Revolution was a concerted human effort in the 1960s to enhance agricultural productivity by altering several traditional practices, such as the use of high-yielding varieties, injudicious use of chemicals as fertilizers and pesticides, and heavy mechanization of farmland. The concept, developed by the American wheat geneticist Norman Borlaug, was trialled first in Mexico and subsequently followed religiously in many developing countries. The reality is that only 25% of the total land area of the Earth is suitable for farming activities. The remainder, which is either too dry or extremely harsh, experiences an adverse climate unsuitable for farming, or a permutation of these. Of this 25%, barely 3% is highly fertile, therefore productive land, 6% yields modestly, and the remaining 13% the output is poor. These are natural limiting factors to agriculture, but processes such as deforestation, desertification, and erosion — the results of mismanaged human activities — are further shrinking the area appropriate for agriculture. For example, of the *c.* 300 M ha of total land area in India, more than 50% is highly degraded and is beyond any redemption. One of the consequences of such mismanagement is the dramatic slowing down of per capita food production. Especially in these parts of the world, concern is mounting on the sustainability of

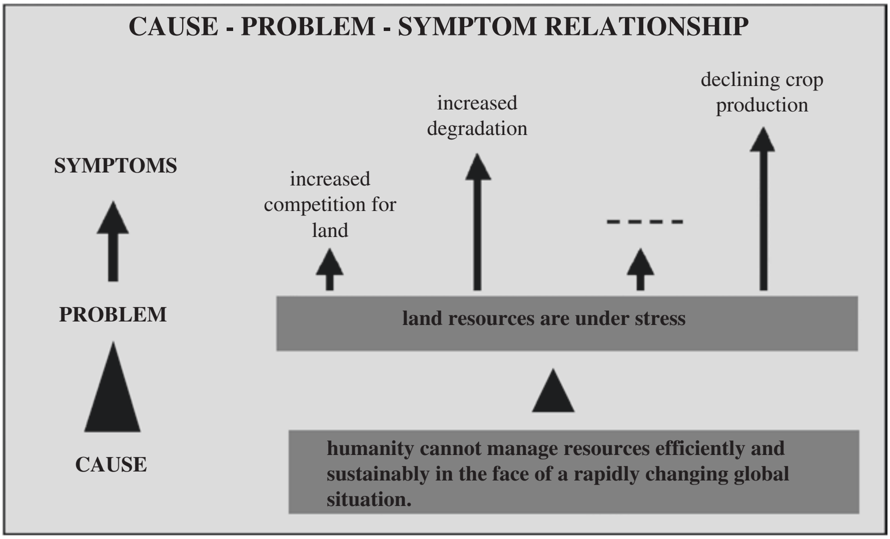


Fig. 1.1 Cause–problem–symptom relationship in stressed land-use pattern. (Adapted from: http://www.fao.org/docrep/004/).

'green revolution', because of continuing and accelerating degradation and destruction of the agricultural material base. In Africa, on an average, 10 times the value of plant nutrients are being removed annually from soil than that is being returned to soil. Overall, more than a third of the total land available on the Earth is being exploited for agriculture. Even in industrialized nations, for example the USA, soil is being eroded close to 20 times faster than it is being replaced (Hall and Hall 1993).

One possible solution for such crises lies in our ability to recognize farmland as an ecosystem: 'the agricultural ecosystem'. Such a perception alone can help us salvage whatever little materials (which will be, according to agricultural economists, 'resources') we still have with us, so that the world can sustain itself productively and usefully to humans and other organisms in the long run. Before the advent of inorganic fertilizers in the nineteenth century, farming depended solely on natural materials for nutrients. Will it be possible to combine the well-established indigenous practices with innovative methods such as new-crop breeds that will respond to low-chemical inputs? To achieve this, we will need models that will suit the circumstances of a particular region's economic and geographic profiles. Those models must also be sensitive to the social and environmental conditions at micro level (Woodwell 1990).

The Agriculture & Environment Conference of 1911 clarified that conventional agricultural practice has been the sole reason for the present environmental degradation (Edwards et al. 1993). The same conference also cautioned that traditional agricultural practices — some of which impress as sustainable — are rapidly disappearing and are replaced by farming practices that depend heavily on finite fossil fuels and associated technologies. To meet the needs for an effective and efficient management of soil, water, and other natural materials, can we aim for and work towards sustaining our production of food, fodder, fibre, and fuel on a per capita basis? Such a refined approach would minimize our dependency on petrochemical and other finite materials, currently used, overused, and abused in conventional agriculture, contributing to the improvement of the quality of soil, water, and other natural materials. Such an approach will improve per capita income and achieve greater equity in distribution. To achieve true sustainability, the human family needs to embrace an understanding in profound clarity that we, humans, are not beyond, but an integral part of nature. Embracing this understanding will involve changing the way we live and how we could organize ourselves sociologically and politically (Edwards et al. 1993; Schaller 1993).

1.2 Ecological Thinking

Ecological thinking arises out of our appreciation of our oneness with nature. Technocentric perception driven by scientific and empirical thinking emphasizes Darwin's Theory of Evolution, laced by the 'survival of the fittest' concept, which has led to human dominance perception. Those who can empathize with the ecological thinking can relate to the 'big' picture and also understand the illusion of human mastery over nature. In reality, we lose sight of the 'self' when we fail to perceive the wholesomeness of nature; also when we fail to perceive that, we are a mere component in the great scheme of things. We need to recognize that nature has its precise mechanism of constant renewal and replenishment of materials, which operates in a cyclical manner. When we humans thought that we have gained mastery — through science and its offspring, the technology — and have thus turned intensely technocentric, we started interfering with the cycles of nature. Eventually, we damaged them to go berserk in many instances and in some to turn linear. Consequent to this transformation from cyclicity to linearity, we are currently facing stunning problems, such as what we identify as 'pollution' and similar, not-so-desirable developments on the Earth. In today's technocentric environment, where economic paradigms rule the roost, ecological paradigms are seen as either 'difficult to practice' or 'primitive' or 'conservative'. To a few others, ecological paradigms appear daunting and challenging.

Movements endorsing ecological paradigms have been occurring throughout the world in different points of time. For example, in Australia, in the second half of the twentieth century, several thinkers have been contributing towards this end. For example, William Mollison and David Holmgren have created the unique 'nature–design system', which has come to stay as permaculture. Customarily, we see ecology as a hardcore science relating to the understanding of interactions of organisms with nature's factors. The offshoot of ecology — environmental science — speaks of strategies that would mitigate issues created by us humans (e.g. climate change). The value of perceiving ecology as a science-based empirical discourse, however, gradually came under close scrutiny in the middle decades of the twentieth century. The borders between ecology as a science and ecology as an art eventually turned obscure in the minds of several eminent ecologist-thinkers, who had previously practiced ecology as a pure, empirical science. This obscurity eventuated in the melding of philosophy on the one hand and ecology on the other (Naess 2008). However, the seeds for eco-philosophical thinking were indeed sown earlier by Aldo Leopold, an American ecologist-forester, who spoke of ‘land ethic’ in his *Sand County Almanac* (1949). Eco-philosophical thinking would be hard to perceive and compartmentalize, but when seen as a major advantage and emotional strength, it enables those that have succeeded to become more intensely creative and innovative. The obscure edges of eco-philosophical thinking — hereafter, ecological thinking — link the measurable scientific dimension of ecology and the immeasurable abstract (plus the partly measurable social) dimension of ecology. Ecological thinking as a distinct paradigm empowers humans with an ability to look within and outside. It is a powerful instrument that bridges empiricism and the abstract, thus providing intelligent and thinking humans a capacity to acquire a powerful vision.

1.3 Development of Agriculture Through Millennia

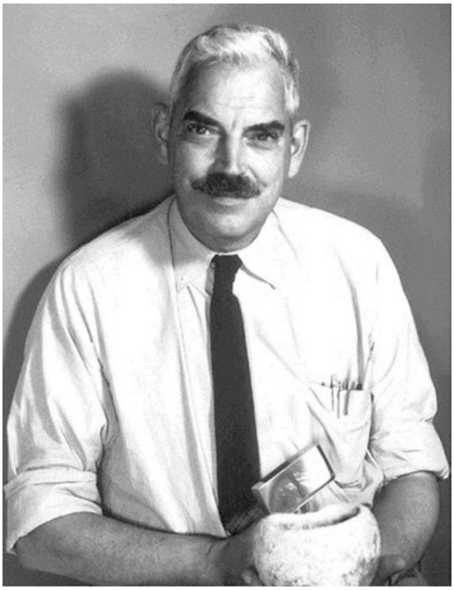
The oldest evidence of organized farming practice comes from Jericho, presently in the Jordan valley. Circa 10,000 years ago, at the spring-fed oases of Jericho, strains of the eventual direction of civilization’s advances manifested. A few other smaller farming communities also flourished near the present city of Damascus and along the Euphrates. Over the next 1000 years in the Near East, domesticated plants and animals provided new and dependable food. These materials were considered dependable, because they could be stored for future needs and had the potential of ever-expanding yields. With the emergence of such agricultural societies, complex human social systems, namely villages, towns, cities, and city states, began to emerge. These systems exercised control over natural landscapes and gradually converted them into agricultural landscapes to feed human populations. It is noted that these modified landscapes produced grains for their populations only: an early presentation of what we today euphemistically call ‘self-sufficiency’.

The Near East and China provide early evidences for ‘organized’ farming. Agriculture, as a practice, seems to have evolved not once or twice, but several times in human history, since different animals and plants have been domesticated separately and independently in different segments of the world. These early agricultural societies expanded to adjacent regions and emerged as independent cultures, because of their confluence with the natural world around them. Against this natural and cultural growth of human societies, we need to contrast the agricultural landscapes of today, when we may realize how close we are, potentially, to the end of nature and its materials that are finite. Recent satellite pictures suggest that close to 20 M ha of rainforests are being degraded and lost annually in several of the tropical countries such as India, Cameroon, Myanmar, and Costa Rica. We also need to realize that the process of trying to transform natural landscapes into economically productive agricultural landscapes — accelerated after the industrial revolution in Europe — received further impetus with developments in agricultural machinery in the 1950s. However, we need to keep in focus that all of this was the continuation of a process that began 8000–10,000 years ago in Asia, and probably in the Western Hemisphere as well, when humans first domesticated animals and plants. Long before the European industrial revolution, humans have been trying to simplify their way of life. Some elementary technologies had been developed, perfected, and used thousands of years before (Valiulis 2014).

How did agriculture begin? What was the sequence in which plants and animals were first domesticated? Why only particular plants and animals were domesticated and not others? What were the wild ancestors of these domesticated plants and animals? Why did agriculture emerge in some regions of the world and not in others? Answers to such questions came from the investigations of the Russian biologist and geneticist Nikolai Vavilov (Portrait 1.1) and the American archaeologist Robert Braidwood (Portrait 1.2). Vavilov (1992), after extensive travels and collecting seed samples from different countries, drew the following conclusions: Because hundreds of varieties of ancient wheat existed in a small, isolated pocket on the Ethiopian Plateau, diversity in cultivated forms resulted from experimentation and deliberate human selection over time. The longer a crop is grown, the more extensively it gets used, and the greater the genetic variety that eventuates within a species. The greater its use by humans, the greater its resistance to pests and diseases. In essence, Vavilov indicated that the geographical area where a crop plant had the greatest diversity of forms would also be the place where it was first domesticated. By locating the centre of a crop's genetic diversity, we can know its epicentre. Vavilov argued that determination of a species' epicentre is critical for biological and genetic research on domesticated plants. However, we know today that the Vavilov theory has at least one flaw: domesticated organisms can, and did, originate in one geographical region and develop their diversity in another. The best examples that illustrate the

Portrait 1.1 Nikolay Vavilov (1887–1946). (Source: https://russiapedia.rt.com/prominent-russians/science-and-technology/nikolay-vavilov/)

Portrait 1.2 Robert Braidwood (1907–2003). (Source: https://msu-anthropology.github.io/deoa-ss16/braidwood/braidwood.html)



weakness in the Vavilov theory are cattle and pigs, which have a much broader distribution than their ranges where they were first domesticated. Another problem would be to locate the wild relative of the domesticated organism. Robert Braidwood studied the Fertile Crescent in the Near East (Braidwood et al. 1983) and indicated the following: (i) Archaeological evidence of the transition to an agricultural way of life in the Near East corresponded with the natural habitat zone for all potential domesticates. This argument was based on his findings that all the wild ancestors of seven major Near Eastern domesticates — barley, emmer, einkorn wheat, goats, sheep, pigs, and cattle — were sourced to the Zagros Mountains in Iraq. (ii) Discovery of the archaeological remains of a farming village at Jarmo dates back by 8000–9000 years ago. The Braidwood team reconstructed the climate when Jarmo flourished, based on sound scientific reasoning. That led to the assembly of evidence for the evolution of a very different way of life, from hunter-gatherer to settlements that later evolved into societies. (iii) Establishment of a human–cultural context is absolutely critical for understanding the evolution of agriculture.

The Vavilov theory based on the present-day plant-distribution patterns and the Braidwood theory based on the past and its reconstruction partly clarify issues of a complex jigsaw puzzle. However, their contributions have provoked several biologists, archaeologists, and historians to investigate the unresolved tiles of the of the gigantic jigsaw puzzle.

The Fertile Crescent in the Near East flourished and developed into a strong agricultural economy around 10,000 years ago. When fully formed *c*. 8000 years ago, it was already the home to plants and animals (e.g. barley, wheat, lentils, sheep, goat, cattle, and pigs) that would form the basis of many agricultural economies flourishing down the ages. In China, the earliest known farming settlements existed along the Yellow River in the north and along the Yangtze River in the south, well before agricultural development in the rest of the world. It is biological evidence rather than archaeological evidence that has contributed to the full picture of the agricultural evolution of Sub-Saharan Africa and Central America. Nonetheless, little is known about the evolution of farming practice in Southeast Asia and South America, although speculation continues on the root-crop agriculture in these regions. A satisfying explanation for the transformation of nomadic hunter-gatherers into organized farming communities is yet to be found. Scholars realize that they need to explain what was different about those particular hunter-gatherer societies where domestication of wild species occurred (Harlan 1992; Smith 1998).

Population growth has been one critical external factor that forced the hunter-gatherer groups to establish into settlements, drawn as they were towards an agricultural lifestyle. Modern interpretations partly reject the population theory and see overpopulation as one of the several unexplainable but interrelated factors. Modern interpretations value regional explanation more than a general, global explanation. Regional explanation more often tends to recognize the transition from nomadic hunting-gathering groups to established societies through a sequence of unresolved developmental puzzles. In the Fertile Crescent, for example, domestication of cereals and goats and the subsequent development of agricultural economies were part of a complex and long-term transformation. This can be better appreciated when we compare and contrast the Levantine Corridor (the narrow strip of land between the Mediterranean Sea and the North African desert), Southern Sahara, and the eastern segment of North America. In all these three regions, seed plants, and not root crops, were domesticated (e.g. barley, einkorn wheat, and emmer wheat in Levantine Corridor; millet, sorghum, and African rice in the southern Sahara; marsh elder, sunflower, chenopods, and squash in eastern North America); wild ancestors of these domesticates were key food items before their domestication; the regional human societies had developed efficient technologies for harvesting and processing seeds; the people who domesticated these plants lived in relatively large, permanent communities, leading a sedentary way of life; and the seed plants in question were cultivated near lakes and rivers ensuring predictable water supply.

1.4 Modern Agriculture: Evolved on the Principles of Technology, Economics, and Management

Agriculture is presently driven by the urge to produce more in small land spaces. Technology's ever-widening capabilities have enabled us to go crazy with this initiative. In the last few decades, we have witnessed tremendous success. Countries that have not been self-insufficient in food production in the 1950s have achieved self-sufficiency in the 1970s and have even started exporting grains. Norman Borlaug sketched the grand design for this landmark achievement. Many developing nations adopted that design and realized self-sufficiency in agriculture. Many developed nations captured the Borlaug design and improved their agriculture significantly and substantially. In numerous instances, nations achieved remarkable monetary gains, as they combined technical and chemical innovations with entrepreneurial opportunism. However, two factors still remained outside the realm of human manipulation: the climate and market. The gains derived from improved technologies were strongly constrained by these two. Simply said, vagaries of climate and market influence and swing agricultural production immensely.

However, contemporary agricultural practice has somewhat understood the roles of climate and market. Developed nations use natural sciences to predict the short- and long-term climate behaviour. They apply management science to predict and understand market in both shorter and longer terms. The guarantee of these predications is, of course, debatable. Nevertheless, achieving greater clarity in these enterprises has empowered developed nations to perform better, given that the other variables in the agricultural enterprise had already been brought under human control. Thus we humans have learnt to fit agriculture into human context. We are fully convinced that the science of agriculture and the business of agriculture need to go hand in hand to achieve better results in production and profitability. Developed nations focused on extensive cropping practice, whereas a majority of developing nations resorted to intensive cropping practice. Developed nations, because of their innate economic capability, attempted producing more and more by employing new science and novel technology (e.g. use of combines, mechanical sowers, harvesters). The developing nations, on the other hand, invariably, use the massive human-power base available to them at low cost and therefore use less-efficient, or sometimes even obsolete, technology. It was, in each of such starkly different contexts, a case of recognizing and then capitalizing on one's competitive advantage that has grown.

To recap what we have seen before, contemporary agricultural practice involves efficient incorporation of animal and plant sciences, agricultural economics, business management, and marketing. The notion of agriculture in developed nations is 'whole-farm business', subscribing to the dictum 'better to solve the whole problem in an approximate way rather than to solve part of a problem in a precise way'.

Management is an integral part of the agricultural enterprise today. It is a powerful tool to remain productive and profitable. Sound agricultural management depends on sound knowledge about farming processes. But fundamentally it requires a skill in juggling diverse components — the intricately intertwined biological, economic, and human components — of a whole farm. However, we need to remember that each component is unique, with its own special characteristics. The success of a farm business relies on the ability of the farmer in achieving his/her goals through efficiency in technical production and sound financial management, targeting profit. Problem-solving skill is another critical dimension of effective management, since different kinds of problems can easily arise in farming and surprise (occasionally 'shock' as well) the farmer. Such surprises and shocks are inevitable in farming, simply because so much of the farm system consists of living material: crop plants, cattle, sheep, and even pests, pathogens, and weeds. Their behaviour as living systems is unpredictable. At least until this point of time, we have no wherewithal to predict them. Each life form thrives in its own set of specific conditions aiming the best performance (e.g. growth, reproduction). But we need to recognize that the farm ecosystem is a fragile system and conditions will usually be suboptimal. Climate is yet another element of that which can spring surprises, since with all our modern technology (e.g. satellite imagery), we still cannot forecast the weather with 100% guarantee.

The gist of agricultural management will be to make the system work at its greatest efficiency with minimum inputs achieving maximum outputs. In contemporary agricultural contexts, outputs will be production and profit, whereas inputs will be a range of biological, economic, and human investments. An efficient farm manager will aim to put together all the inputs so that he/she will achieve as many of the desired, which will become the prescribed objectives within a determined time frame. A clever manager will also keep in view the fact that not all of one's objectives can be realized fully, and there will be inevitable trade-offs. But that clever manager will also remember that he/she will make every possible effort to minimize trade-offs, by judiciously assessing the risks involved and implementing appropriate remedial measures at appropriate times. A thorough manager will also make right judgements by analysing and assimilating the past information and experience, along with incorporating current research information. Right judgements have always enabled good decisions. A sound understanding of scientific principles always predisposes a manager to making more well-founded management decisions. Science is an intellectual procedure that seeks to explain the cause and effect relationships between two aggressive variables in the contextual ambience of several related, less-aggressive variables. Scientific thinking and ability enable the farmer to perceive the role of either an individual or multiple factors that influence a process. Scientific reasoning operates either by simplification and excluding the factors except those being investigated (reductionistic practice) or by looking at large parts of production systems and by measuring the performance of various parts collectively and cohesively (holistic practice) (Raman 2013a).

Recognition of the finiteness of materials (e.g. natural, human, and financial) is the force that drives Environmental Economics, which seeks to explain their distribution on the basis of how governments provide options of their management via support and subsidies. Is this a reasonable approach? Today, Environmental Economics is considered a scientific discipline, yet one innate strength (or weakness?) is that it traditionally considers social outcomes more aggressively than environmental outcomes. Humans are fundamentally driven by their emotions, and science tends not to get involved in asking questions about this. Environmental economists, in their effort to offer solutions to complex social problems, generally tend to simplify the complexities of the human world into variables that can be decoupled from the rest for measurement, losing the organic interconnectivity of a society's living processes.

The critical thing to recognize here is that the dynamics of farm practice involves the appropriate blend of science and economics, so that the most desired outcomes — productivity and profitability — are realizable. A purely scientific approach to deal with farm practice and agricultural problems, divorced from economic necessities and realities, will only provide a partial solution, and a purely economic approach that ignores scientific trials and practice will be just as flawed.

1.5 Precipitation of Crises

Thus far, I have drawn your attention to three closely knit, complex matrix of industrialized (conventional) agriculture: (i) adoption of efficient technology, (ii) clear economic goals, and (iii) clever management strategies. This matrix contributed in a major way to a rapid degradation of the Earth's limited land, for instance. The magnitude of the problem is clearly demonstrated in Australia. From the time of the arrival of the Europeans to 1975, 45% of agricultural land badly needed remediation, because of various forms of degradation inflicted to that land because of farming practices. For example, soil erosion increased dramatically with the introduction of European-farming practices in Australia during that time (Woods 1984). Extensive removal of native vegetation, to make room for farmlands, exposed the land, destabilized soil structure, and contributed to soil erosion by water and wind. Intensive cultivation practices have resulted in loss of organic matter on topsoil and damaged the soil structure resulting in reduced capacity for infiltration and surface waterlogging. Degradation of vegetation was another obvious result of European-farming practices. Natural plant-population clusters became scanty, losing their density and vigour. The proportion of native perennials, which mostly constituted the natural vegetation, declined in a substantial manner, resulting in vast tracts of vacant land, thus making it vulnerable to invasion by undesirable plant elements. A fabulous example comes from the distribution of the most-dreaded *Parthenium hysterophorus* (Asteraceae), which has spread across almost all of the vast tracts of erstwhile rich pastureland of Queensland (e.g. Mitchell Grass Downs and Brigalow Belt) (Fig. 1.2) (Dhileepan et al. 2018). One dramatic and far-reaching outcome of clearing of native trees for agriculture in Australia is dryland salinity (Fig. 1.3). Native vegetation included long-living (perennial) woody-tree species that transpired large volumes of water and maintained groundwater far below the soil surface. In the wake of modern agriculture, vast tracts of scrub and forest land have been cleared and replaced with short-lived herbaceous plants, which utilize less volumes of water. Eventually, groundwater moved upwards, bringing the deep-seated Na and K salts up to the surface (Cocks 1992). Soil acidity, due to land mismanagement — injudicious use of fertilizers such as super-phosphate and other synthetic fertilizers and absolute removal of crop residues from the land which has the capacity to neutralize the soil's acidic content — has risen (Cumming and Elliot 1991). Available soil nutrients have tapered to micro quantities. Uninterrupted cultivation drained them and that in turn induced decline in the quality of soil structure. To replenish nutrients, farmers started injecting synthetic fertilizers (Derrick and Dann 1997). Similar to the recent surge in the use of synthetic fertilizers to strengthen the weakening soil, we have been using violent and aggressive chemicals, such as dieldrin, heptachlor, and DDT, to keep pestiferous arthropods and pathogens under control. Although these applications did offer immediate benefits, we now realize that they have caused more harm to the soil. Residues persist in the soil and build up exponentially, which in turn have been damaging the soil biota and their fascinating diversity. Such issues arising out of badly thought of land-use patterns occur plentifully throughout the world.

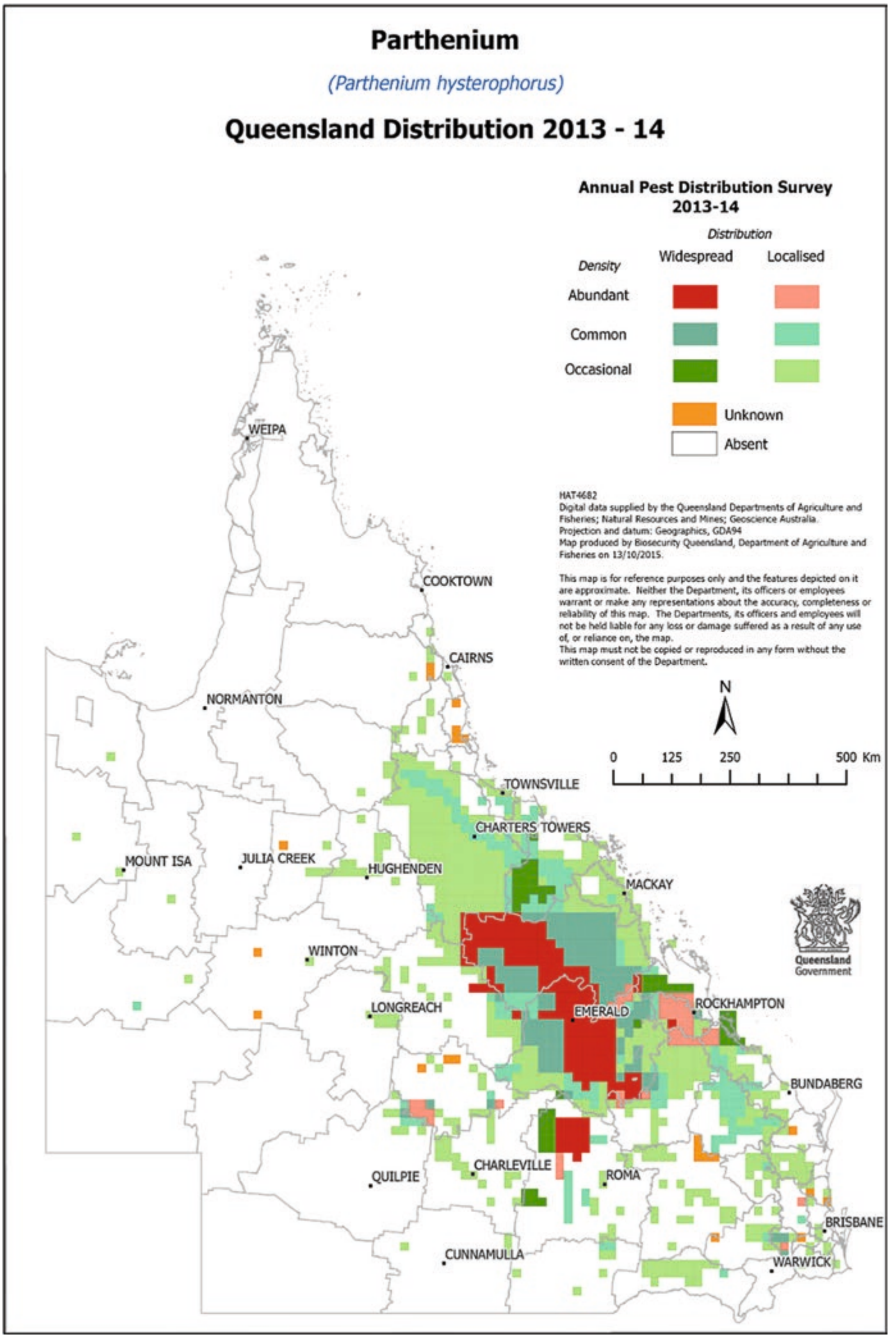


Fig. 1.2 Distribution of *Parthenium hysterophorus* in Queensland (Australia). (Source: https://www.daf.qld.gov.au/__data/assets/pdf_file/0003/790491/Parthenium_2013.pdf [Courtesy: K. Dhileepan, Queensland Department of Agriculture & Fisheries, Brisbane and the Queensland Department of Agriculture & Fisheries, Brisbane, Australia])

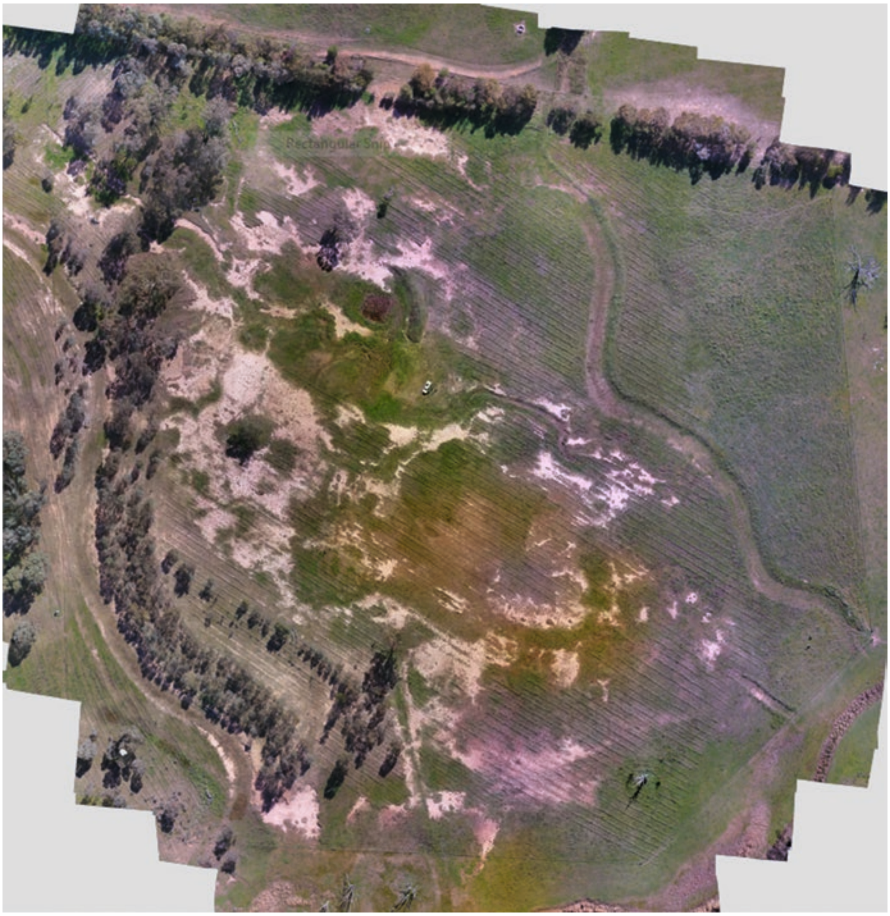


Fig. 1.3 Aerial imagery (drone photography) of a representative landsite (Sloanes Creek, Central-West New South Wales, 32°85′ S, 148°93° E, head-water catchment: *c*. 580 ha) showing prominent salinity-induced scalds. (Courtesy: David Mitchell, Department of Primary Industries, Government of New South Wales, Orange, NSW, Australia)

1.6 Sustainability

In many parts of the world, we have been inducing significant alterations to our natural environment, simply because economic criteria dominate over ecological criteria in our land-use decisions. The clarion call of Rachel Carson (1963) conscientized many of us of the extent of the critical and long-term damage such alterations could cause to our biophysical environment and, consequently, to our agricultural efforts. We began searching for a model that would enable us to achieve both economic and ecological goals — a sort of 'win–win' situation — so that the Earth can provision the materials for a longer period than our present economics-driven agricultural practices will allow.

At this point, we need to reflect on the question 'how did our ancestors manage their environment?' We need to know how pre-industrial civilizations coped with climate change, which certainly existed in those times as well (Pain 1994): (i) It was not so much climate change that caused problems, but the entrenched modes of adaptations to change. (ii) Such responsiveness depended on individual and collective choices, which were, of necessity, shaped by the past. (iii) The development and use of knowledge was the main mechanism for survival in conditions of rapid change. This means that adaptation to changing conditions depended on the perception and interpretation of the signs of impending change, on the timely development of knowledge, technology, and organization in reaction to those signs. (iv) By virtue of their privileged position, the elite who had a formal and social mandate to lead were often shut off from direct or even indirect experience of the signs of change. They had the power to maintain their lifestyles and the way things were when it was no longer prudent to do so. These perceptions enabled growing numbers of people to accept the concept of sustainability, a concept that could help us develop a set of guiding principles and goals to promote equity between and within generations of humans. Working for these outcomes will involve us in (i) maintaining the Earth's life-support systems and (ii) improving individual and community well-being.

In contrast to such a broad-based ecological perception of sustainability, economists would generally think of sustainability in narrower terms of maintaining consumption at a constant level forever. Unfortunately, economic thinkers seldom recognize that degradation of the biosphere will eventually dry up society's spending power. If we were really living in ways that would secure food consumption in the future, we would also be monitoring and regulating the use as well as abuse of our biophysical resources (Diesendorf 1997). Carson's *Silent Spring* received several follow-up commentaries in the 1960s (e.g. Boulding 1966; Mishan 1967), which stirred public, scientific, and political debates on achieving sustainability. The United Nations convened a conference on the Human Environment in Stockholm in 1972. Perhaps the most significant of the then prevailing thoughts was that of Meadows et al. consolidated in the publications *The Limits to Growth* (1972) and *Beyond the Limits* (1992). Meadows et al. illustrated the material and environmental limits to future growth in the way we use materials and energy. Their global model suggested that industrial capital would depreciate faster than any new investment could rebuild it. In brief, the global outlook was painted bleak and catastrophic. However, the Meadows et al. viewpoints have been received with considerable resentment from practitioners of economics.

In the 1980s, public consciousness of environmental issues, such as changes in global climate patterns, deforestation, and pollution, increased substantially. The newly formed green political parties gained representations in local, regional, and national governments. The United Nations set up the World Commission on Environment and Development in 1982 under the chairmanship of Gro Harlem Brundtland. The Brundtland Report, titled *Our Common Future* (1987), heralded in the concept of sustainable development, defining it as 'the development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. The weakness of this definition is that it does not explain either development or needs. The word ‘needs’ is confusing, since it relates quite generically to both ecological sustainability and economic wants. However, the body of the report does refer to issues such as equity between and within generations, conservation of biodiversity and ecosystems, dealing cautiously with risk and uncertainty, economic development and well-being, and community participation. This report emphasizes economic development, but suggesting a different meaning from economic growth. As a follow-up of the Stockholm Conference, the Earth Summit held in Rio de Janeiro in 1992 facilitated several international negotiations and decisions related to the environmental security of the Earth, its biophysical materials, and the people (Grubb et al. 1993; Turbayne 1993).

1.7 Sustainability and the Natural-step Framework

The stark reality is that agriculture is a commercial enterprise. How can a commercial enterprise design its activities for a sustainable future? The natural-step framework (Nattrass and Altomare 2001) offers a cohesive linkage between commercial enterprise management and environmental management by exploring a concept called corporate sustainability, building on the following: (i) The whole structure of industrial society is based on a faulty design. Ours is a take–make–waste society that violates the conditions for sustainable human life on the Earth. To understand the problem, we need to take a natural systems view of our society and its relationship to the environment. (ii) Although the elements of the problem are complex in their many dimensions, the core issues are easy to understand through the conceptual framework. (iii) It may not be too late for industrial society to take action, if we act now. There is no more time for business as usual. It is not necessary or important to assign blame. It is necessary to take action, to change our present unsustainable course. (iv) Humanity is now able to take its evolution into its own hands by conscious choice and design. Some innovative companies are already taking conscious evolutionary action, and some of those are using the natural-step framework in that process. The natural-step framework provides an elegant and simple design to integrate environmental issues into the frame of business reality and to move the enterprise towards sustainable development. It includes four core processes: (i) perceiving the nature of unsustainable direction of business and society and the self-interest implicit in shifting to a sustainable direction; (ii) understanding the first-order principles of sustainability, i.e. the four system conditions; (iii) strategic visioning through backcasting from a desired sustainable future; and (iv) identifying strategic steps to move the company from its current reality towards its desired vision.

1.8 The Challenge of Ecological Sustainability

We earlier saw that the term ‘sustainable development’ gained global acceptance after the recommendations made by the UN-sponsored World Commission on Environment and Development (UNCED) (The Brundtland Commission 1987).

From that time on ‘environmental sustainability’ and ‘sustainable development’ are being discussed in many quarters around the world.

The environmental sustainability concept originated essentially out of social concerns: seeking improvement in human welfare by protecting the raw materials used by humans and by ensuring that the sinks for human wastes do not overflow (Goodland 1995). Environmental sustainability is a social goal that will only be realized when humanity learns to live within the limitations of the biophysical environment, by purposefully maintaining the Earth’s natural-material capital both as biomass and as a sink for wastes. Achieving this will also preserve the economic subsystem of the Earth’s ecosystem. The critical factor will be to strike a judicious balance between production and consumption. Of course, any depletion of non-renewable resources is unsustainable in the strict sense of the term; however some conservationists argue that modest use of materials will be acceptable, provided their depletion rates are somewhat equal to the rate at which renewable substances can be created.

Sustainable agriculture incorporates three arms of sustainability: social, environmental, and economic. Any development activity should not only be socially acceptable and economically viable but also environmentally sensitive. The broad focus in the context of sustainable agricultural development will be the overall improvement of the well-being of humans by reducing poverty, hunger, and eventually disease, simultaneously maintaining the human-support system, the natural capital, which includes the environment’s sink (for the waste materials) and source (natural materials). Global human consciousness has now evolved into a widespread appreciation that our assets as a species include natural-material capital. The notion of environmental sustainability builds on this awareness and focuses our concern onto the present state of our soil, atmosphere, water, forests, and wetlands. Our ecosystems need, at the very least, to be conserved, or better still, conserved and given the security of a global commitment to their not being put at risk again, plus strategies and works on the ground to make this more than rhetoric.

1.9 Has Economics, as a Discipline, Responded Positively?

The answer perhaps is ‘not’, as wholesomely as the occasion would demand. Prevailing models of economic analysis treat consumption of natural capital as income, and such an approach promotes unsustainable patterns of economic activity. Consumption at the cost of natural capital is not income. Common sense prompts us to recognize that our means of producing income needs to be sustainable, but at the present rate of consumption, natural capital is becoming slimmer, scarcer, and scantier. Consumption of natural capital will lead to liquidation. Environmental sustainability needs thought, effort, and action that has a conservation focus. It is time that we accepted that natural capital is no longer a commodity to be used indiscriminately and injudiciously, but to be used with extreme prudence and care.

The view that environmental sustainability is critical only for (and in) developing countries is a myth. It is the developed countries — not only in per capita terms but also in absolute terms — that have precipitated so much of the Earth’s environmental changes. Developed countries need to adopt environmental sustainability measures more quickly and vigorously than the developing countries (Goodland et al. 1992). However, Goodland's argument does not extend to the issue of the conservation of biodiversity, because a majority of the Earth's biological materials remain in tropical ecosystems that are generally distributed in the poorer belt of the Earth. In the longer run, developing countries will gain for themselves and contribute to the Earth as a whole only as they apply the precautionary principle (Raman 1998).

Environmentally sustainable development does not require us to make a simplistic choice between socially desirable activities and extractive policies. It is a combination of both; more than that, it seeks to strike a desirable balance between the two, which is hard in practical terms. The level of hardness will be intensely experienced in developing countries, because the conservation of natural materials for future needs will need to be viewed against the people's immediate necessities to lead a decent life of minimum comfort. Nevertheless, what would be 'minimum comfort' is a debatable point. One major strength of the human species is the ability to act with hindsight and forethought. Yet, the major weakness is that many of our current development activities are self-centred, despite a greater understanding of ecology and entropy. We seem to be oblivious to the antithetical relationship between the fast-shrinking natural-material capital and the ever-growing human population. We need to realize that ignorance of such an inverse relationship between two such critical variables is threatening and thwarting our survival. On the one hand, there is an urgent need for action among the world's governments and corporations and, on the other, just as urgent a need for an individual and community response!

1.10 Conservation of Biological Diversity and Ecological Integrity

Biological diversity, also referred to as biodiversity (Wilson 2010), refers to the variety of life on the Earth and as such is an essential aspect of the basic life-support systems for humans and other living beings. Normally, we recognize (i) genetic biodiversity, (ii) species biodiversity, and (iii) ecosystem biodiversity. Genetic biodiversity is the information contained in the genes of different organisms (e.g. microbes, plants, animals) on the Earth. Species diversity refers to different 'kinds' (variety) of organisms on the Earth. Estimates indicate that there are anywhere between 5 and 50 M species on the Earth, although only close to 1.4 M have been formally known. Ecosystem diversity refers to the variety of habitats, surviving communities, and the interconnecting ecological processes in the biosphere. One major influencing reason to recognize biological diversity is the rate at which organisms are becoming extinct. For example, since the colonization of Australia by Europeans nearly two centuries ago, c. 10% of mammalian species have become extinct (Woinarski et al. 2015). Of the known 20,000 plant species, close to 100 have become extinct and about 3000 are currently under the 'severely threatened' status (Fitzsimons et al. 2010). The principal threat to biological diversity is either the destruction or the fragmentation of habitats due to development activity.

Introduction of feral animals and plants and injudicious application of synthetic fertilizers and chemicals into the land have indeed accelerated the process. We need to keep in view that diversity of organisms provides us with materials that supply food, clothing, pharmaceuticals, fuel, building materials, and further to many other products and services, which can withstand measurement and valuing in economic terms.

Ecological integrity orchestrates biological diversity, and biological diversity contributes to ecological integrity. Balance in the ecological functions of ecosystems (e.g. carbon fixation, nutrient cycling, regulation of microclimate) is possible because of biological diversity. Ecological integrity also enables the maintenance of the evolutionary potential necessary for adaptations in organisms to changing environmental conditions. Economists interpret this as the conservation of a representative sample of each existing species, gene types and gene flows, and ecosystem somewhere on the Earth. Economists' perspective entails a high probability of an ecological collapse, because it accepts the dispensability of all but that one, single surviving remaining 'representative' ecosystem. The net loss of biodiversity under this regime cannot be measured, but estimated to be vast, extensive. We know minimum populations are necessary to maintain survival, but we cannot quantify what those minima are.

1.11 Other Related Influencing Dimensions of Ecological Integrity

1.11.1 Cultural Diversity and Its Conservation

Colonialism of various countries by different European kingdoms in the seventeenth and eighteenth centuries contributed tremendously to loss of cultural diversity across most parts of the world. This loss was accelerated because of growth and spread of mass media in the twentieth century. Dominant societies were destroyed (Wolfe 2006). Some attempted to suppress cultural diversity of invaded landscapes and some even tried to homogenize them with theirs (Fernandez 2014). This resulted in the failure to protect languages, social structures, and economic and political beliefs of native groups of people. We need to remember that these less-known cultures and social systems in many instances have evolved more ecologically sustainable and socially equitable ways of living, and we may need to draw upon the knowledge and experience of such groups and model them (Haverkort and Hiemstra 1999). In other words, sustaining cultural diversity is a key tactic in sustaining biodiversity and thus ecological sustainability of agriculture.

1.11.2 Individual and Community Well-being

This transcends conservation towards enhancement, because its goal is the improvement of individual and community welfare by following a path of economic progress that does not impair the welfare of future generations. Despite the ambiguity with the terms 'economic progress' and 'growth', this will aim at valuing a form of development in which society does not reach an irrevocable stage of either universal hardship or universal poverty. The term well-being has a wider connotation than being purely economic, because a set of ecological, social, political, and economic meanings can easily be drawn as inferences from it.

1.11.3 Intergenerational Equity

Equitable treatment of future generations is fundamental. However, what remains under debate is what should be handed down to future generations: the health or the diversity or the productivity of the environment? Or, all the three together? Earlier cited principles offer some leads to answering these questions. We should be able to pass on not only the primary, minimalist aspects of biological and cultural diversities but also the enhanced qualities of those principles as well. In effect, the principle of intergenerational equity plays a key role in tying together the minimalist and enhanced outcomes. Nevertheless, two ethical questions arise at this context, on which we need to reflect with extreme caution:

- What are the present generation's responsibilities to future generations?
- Since we cannot survey the views of our children's children and beyond, how best can we help them?

1.11.4 Community Participation in Decision-Making

The value for this emerges from the recognition that decisions about technological and industrial development not only involve the proponents and the government but also, and more importantly, other community stakeholders, such as the direct and indirect consumers, environmental activists, and health workers. These stakeholders hold a body of knowledge and experience that often collectively exceeds that of the dominant stakeholders.

1.12 The Precautionary Principle

The precautionary principle proposed by O'Riordan and Cameron (1994) recognizes and validates 'uncertainty' and recommends that this element of uncertainty should not be used as an excuse for doing nothing, shifting the onus of proof away from opponents to proponents, and taking anticipatory and preventive action. In the context of ecological–agricultural sustainability, the precautionary principle can be extrapolated with varying degrees of strength, depending on how either serious or significant the problems triggered by the application of this principle would be. Varied interpretations and extrapolations exist in the context of ecological sustainability and sustainable agriculture. For example, the Australian Intergovernmental Agreement on the Environment (Government of Australia 1992) indicates:

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment and an assessment of the risk-weighted consequences.

On the other hand, the British Government's environmental white paper (Chancellor of the Duchy of Lancaster 1993) indicates:

> Where the state of our planet is at stake, the risks can be so high and the costs of corrective action so great, that prevention is better and cheaper than cure… Where there are significant risks of damage to the environment, the government will be prepared to take precautionary action to limit the use of potentially dangerous materials or the spread of potentially dangerous pollutants, even where scientific knowledge is not conclusive, if the balance of likely costs and benefits justifies it.

Many see the precautionary principle as an environmental insurance, taken out by those who are disinclined to gamble on ecosystem malaise or even shutdown. The benefits coming from a precautionary approach will not necessarily be recognized however, simply because nature-driven ecological processes have –follow-on effects beyond the limits of our powers of observation. This explains why so many land developers and progress-oriented politicians never see any value in O'Riordan–Cameron's precautionary principle. We recognize, as a fundamental, that no matter who takes a position on the principle of precaution, no matter what the position is, views are informed by one's value judgements and thus are the subject to challenge.

1.13 The Scale of Ecological Sustainability

As we discuss ecological sustainability, it will be important that we place the discussion in the context of a scale — scale of time and space — so that we can consider the 'magnitude of change' and the 'velocity at which change would occur'. Change has always been occurring in the context of every living being. It is implicit in the notion of evolution. And the same fluidity is built into the notion of ecosystem: interactions and life forms are equally susceptible to change. As species reach the limit of their capacity to change, they become extinct. But we need to recognize and realize that what we described earlier as behavioural change in organisms and the consequent evolution within a species would have occurred in fractions of time for microbes, such as bacteria, and in massive periods of time for larger animals and humans. Because a given ecosystem includes species of greatly varying complexity — the more diverse an ecosystem, the more resilient it is — we need to be cautious not to oversimplify our picture of the kind of change that a given ecosystem may be undergoing, because many different timescales are involved, and many of them overlaid in highly complex manner. The human-induced greenhouse effect violates ecological sustainability because it is causing changes within several decades in the climate system whose natural changes of similar magnitude would require several millennia or more. Similarly, soils which took thousands of years to build up are being lost in a few decades. The concept of ecological sustainability needs to be applied on the spatial scales of the whole planet, continents, individual countries, and even at the scales of ecosystems such as biological regions tapering down to far smaller natural reserves. Our modern understanding of the economic concept of sustainability relies heavily on the Hartwick model (Common 1995). The Hartwick model proposes that if a given, constant population consumes a non-renewable energy for which a human-made substitute exists, then economic sustainability can be achieved if the profits of this consumption are invested. However, this model only works under several restrictive assumptions, and many of them have not been tested yet. More research is necessary to produce a practical and implementable version of economic sustainability. Within the existing economic models, sustainability is concerned with maintaining consumption at some constant level for a long, but unspecified period of time. Economists generally seek the maximum constant rate per capita consumption that can be maintained indefinitely. The interesting paradox of this approach is that once the sustainable level of consumption is achieved, economic growth will be superfluous and unnecessary. It remains to be seen whether economic sustainability defined in this way entails ecological sustainability and vice versa.

1.14 Alternative Practices of Agriculture

In earlier sections, we saw how agriculture evolved over thousands of years and how the industrial revolution in Europe changed human perceptions of agriculture rather dramatically, and, with the onset of growing concerns on the exploitation of land and other natural materials indiscriminately, how we began to look at options of sustainability. We also considered briefly the ongoing debates on the terminology and meanings of the twentieth-century terms namely sustainability, sustainable development, environmentally sustainable development, and ecologically sustainable development. Here we will look at the forces that encouraged some people to think differently from the conventional practice of agriculture. We will see the origins and evolution of alternative farming practices developed by some of the thinkers who thought outside the box. We need to remember here that the effort at this stage is only to illustrate how the thought processes began and why such leaders thought differently.

1.14.1 Organic Farming

Organic farming evolved with time by European farmers who were not convinced of the conventional farming practices that deeply engaged in manipulative techniques to reduce human effort and increase yield. The stimulus for this paradigm arose from Humphrey Davy's (1813) and Justus von Liebig's (1840) explanation that plants absorbed those minerals in humus and manure, and not from soil organic matter. Both Davy and von Liebig argued that inorganic mineral fertilizers could replace natural manures and bring agriculture under science-based management (i.e. technocentric approach), enhancing production and efficiency. This breakthrough led to agricultural revolution facilitating industrialized agriculture. In brief, the following can be seen as the goals of organic farming — sustainable methods of farming, avoidance of pollution, welfare of animals, and use of renewable resources. However, on a commercial scale at least, organic farming is an approach that seeks to secure financial viability, as well as the output of quality products within predictable time frames (Kristiansen and Merfield 2006). This can be achieved by skilful farmers drawing on scientific wisdom (Murphy 1992). Farmers by and large like to produce better food or fibre than their neighbours, or at least as well. But of course, the quality and quantity of production are constrained by various factors, including environmental conditions, and so comparisons with one's neighbour's performance have to be drawn with care. In an age where 'Landcare' as in Australia (https://landcareaustralia.org.au/) has become so effectively implanted on the psyche of farmers, healthy competition between producers is also extending beyond the economic bottom-line to environmental and social outcomes. Increasingly, farmers on both sides of the 'organic divide' are concerned about long-term impacts of agriculture on the farm and the catchment (landscape, watershed) and about other value-added issues, such as farm-animal welfare (Newton 1995).

1.14.2 Rudolf Steiner's Biodynamic Farming

One other alternative practice developed in the 1920s is biodynamic farming. Thoughts of biodynamic farming coincided with the onset of agricultural intensification. However, the alternative modes of farming — better designated as eco-farming — became excellent models for sustainable farming (Rat der Sachverständigen für Umweltfragen 1985). Biodynamic farming, with the development of its knowledge system and its diffusion, provides an example of the driving and inhibiting forces that govern any sustainable innovation that affects and involves society (Gerber and Hoffman 1998). The knowledge base of biodynamic farming includes:

- All the know-how and facilities necessary for producing, processing, marketing, and consuming products within the farming system
- The epistemology (theory of the methods or grounds of knowledge) and its influence on sociocultural context
- The institutions supporting the promotion of these processes. Can the spece among the three dot points be reduced?

Biodynamic farming voluntarily restricts itself to the use of certain management options. This is a special feature of its epistemology and a key reason for its environmental compatibility. Mainstream natural science proposes that nature is a more complex version of inanimate matter; this view flows from the premise that the total can be described as the sum of its parts. Biodynamic farming, on the contrary, represents the view that only the relationships between elements in a biological system can be described by chemical and physical laws, not the organism because it functions as a whole. An organism has a history which influences its behaviour, has activities and variability, and has inbuilt means of organizing its living processes, all of which indicate a higher order. It was the German scientist, poet, and philosopher Johann Wolfgang von Göthe who offered this explanation. His thought was picked up later by Rudolf Steiner of Austria and developed into biodynamic farming, the oldest variant of ecological farming (Gerber and Hoffman 1998).

Steiner (1924) departed from the organic understanding of nature. He proposed that farming needs to be seen as the task of the shaping and managing the farm as an organism. The farm should develop an agricultural individuality in its physical location, taking into consideration the economic and social conditions of that location. In brief, biodynamic farming follows the principle that the farm is a goal-oriented organization of agricultural production which is to a large extent self-sufficient and internally balanced.

Conventional modern farming seeks to suppress the so-called undesirable elements in the agro-ecosystem and introduce the so-called desirable elements, for example, by manipulating the species mix with synthetic chemicals. In contrast, biodynamic farmers seek to make use of even a partial knowledge of — but with a fulsome respect for — ecological processes and relationships and intervene by stimulating natural processes (Schaumann 1977; Köpcke 1994). Ecologically sound interventions, even only when implemented in a modest area, are nevertheless seen as a significant step in the realization of their cosmovision (Beekman and de Jonge 1999). Eco-farming, proclaimed as biodynamic farming by Steiner, has evolved since then, through a range of processes involving farmers, advisers, processors, and consumers, into a significant alternative food supply system in many parts of the world. It has become a movement, in the sense that supporters of Steiner's biodynamic principles see them as not only channelling their lifestyle but also informing their worldviews. Thus, for instance, in some countries, schools are set up to provide primary and secondary schooling, following a Steiner-inspired curriculum.

Some guiding principles of biodynamic thought are shown below (Dewes and Schmitt 1995):

- Biodynamic farming offers a perspective for future sustainable agriculture.
- The knowledge system of biodynamic farming is threatened by external pressures.
- Biodynamic farming will only remain as an alternative for action, if it defends its knowledge system.
- Biodynamic farming will only be sustainable if its knowledge system develops further.
- The knowledge system of biodynamic farming offers an ethical model for action.

1.14.3 Masanobu Fukuoka's Natural Farming

Fukuoka's natural farming aims at reversing the degenerative momentum of modern agriculture. Natural farming needs no machines, no chemicals, little weeding, no ploughing, nor application of prepared compost. Fukuoka distinguishes his concept of natural farming as one that cooperates with nature rather than trying to improve it by what he terms as 'assault' and 'conquest'. Fukuoka's inspiration to develop natural farming arose from his perception of the degeneration suffered by the land and Japanese society from the 1940s. He was determined to remain committed to Japanese traditional farming practice; however, he refined the process in such a way that his natural farming would demand less labour and less disruption of nature than any other, while maintaining same yields as his peers.

Fukuoka's natural farming is constructed upon the interconnections of farming practice with aspects of Japanese culture and the spiritual health of the individual. His perceptions arise from the belief that healing of the land and purification of the human spirit are the same process; his proposal reinforces the relationship between the two. He proclaimed that natural farming is, in principle, a way of life that is marked by an ongoing process of attitudinal change. As a young man, Fukuoka left his rural home to pursue a career as a microbiologist in the city of Yokohoma. Working as a plant pathologist for some years in a laboratory, Fukuoka was successful in applying principles of Western agricultural science; however, that success frustrated him since his career remained steady and uneventful. It was in 1938, when he was 25 years old, that he went through a rigorous period of introspection, during which he questioned the long-term viability and validity of western, techno-centric agricultural science. In a dawn of vision, he realized that all accomplishments of human civilization are meaningless in front of the wholesomeness of nature (Fukuoka 1987). This realization formed the message of his life's work. He returned to his native village to test the soundness of his ideas by applying them in his own fields. The basic idea came to him as he happened to pass an old field, which had remained unploughed and unused for many years. In that old field, he saw healthy rice seedlings sprouting through a tangle of grasses and weeds. From this clue, he stopped flooding his field to grow rice. He stopped sowing rice seed in spring and, instead, put the seed out in autumn, sowing it directly onto the surface of the field. He learnt to manage weeds with a permanent ground cover of white clover and a mulch of rice and barley straw. Once the crop was established, he learnt not to interfere with the plant and animal communities in his field (Korn 1978). In the 1970s, Fukuoka harvested 1100–1300 lbs. (c. 400–500 kg) of rice per quarter acre which was approximately equal to the rice production systems following chemical or conventional farming methods. Although the results were comparable, the impact each of these methods left on the soil was different. Fukuoka's soils always improved in quality (e.g. fertility, structure, and capillarity and retentivity of soil) with time. Disease agents and damaging insects are always to be expected in farming, but Fukuoka thought the crops can never be devastated, because only the weak plants are affected; the best management strategy for disease and insect control is to grow crops in a healthy environment.

1.14.4 Bill Mollison's Permaculture

The Australian concept of permaculture evolved on the organic farming principles of Fukuoka. Bill Mollison founded the permaculture movement with part support from David Holmgren. Mollison regards permaculture as a philosophy for working with, rather than against nature, an approach more characterized by extended and thoughtful observation, rather than protracted and thoughtless labour, an observation of plants and animals in all their functions, rather than as separate elements of single-product systems. Permaculture also emphasized the idea that the human species is in no way superior to other life forms. A culture that cannot relate to this dictum is capable of destroying any living thing. In passionate terms, permaculture encourages farmers to see opportunities, not threats, to see solutions, not problems (Mollison and Slay 1991).

Proponents argue that permaculture is a system that allows us to exist on the Earth by using energy that is naturally in flux and relatively harmless and by using food and natural resources that are abundant, in such a way that we do not continually destroy life on Earth. Permaculture, a holistic concept, aims at decreasing energy consumption and at encouraging humans to take part in food production, at least indirectly by supporting a responsible food crop grower. It also aims at meeting all energy needs from within the system. When this is not achieved, we pay the price in energy for consumption and consequent pollution. True costs of agriculture become no longer viable and affordable, and therefore, in effect, we kill the world and the world in turn will kill us. We need to strike a chord of cooperation with the living and non-living objects that surround us. Cooperation entails harmony; opposition brings chaos and disaster.

Permaculture advocates the care of Earth (Table 1.1), which means care of all living beings and non-living objects. It implies harmless and rehabilitative activities, active conservation, ethical and frugal use of resources, and the right livelihood. This philosophy also recognizes and values the intrinsic worth of every living thing. A tree is something of value in itself, even if it has no commercial value for us. It is alive and functioning is important. It is performing its part in nature. For example, it is recycling nutrients and biomass, providing oxygen and utilizing carbon dioxide for the region, sheltering animals, and building water and soil. Thus permaculture pervades all aspects of environmental, social, and economic systems. Cooperation and not competition is the key.

1.14.5 Henri de Laulanié's System of Rice Intensification

Henri de Laulanié SJ, a Jesuit priest in Madagascar, developed and perfected a technique that is popularly known today as the *System of Rice Intensification* (SRI), which reinforces the prudent and economical use of water in rice paddies, which was hitherto perceived as an 'aquatic' plant. Laulanié's report (1993) published in *Tropicultura* (Brussels, Belgium) supplies comprehensive details of his multiple trials made in the rice paddies of Madagascar. Overall, SRI minimizes

Table 1.1 Earthcare Ethics

Think about the long-term consequences of your actions. Plan for sustainability
Where possible use species native to the area, or those naturalized species known to be beneficial The thoughtless introduction of potentially invasive species may upset natural balances in your home area
Cultivate the smallest possible land area. Plan for small-scale, energy-efficient intensive systems rather than large-scale, energy-consuming extensive systems
Be diverse, polycultural (as opposed to monocultural). This provides stability and helps us to be ready for change, whether environmental or social
Increase the sum of yields: Look at the total yield of the system provided by annuals, perennials, crops, trees, and animals. Also regard energy saved as a yield
Use low-energy environmental (solar, wind, and water) and biological (plant and animal) systems to conserve and generate energy
Bring food-growing back into the cities and towns, where it has always traditionally been in sustainable societies
Assist people to become self-reliant, and promote community responsibility
Reafforest the Earth and restore fertility to the soil
Use everything at its optimal level and recycle all wastes
See solutions, not problems
Work where it counts (plant a tree where it will survive; assist people who want to learn)

Source: Modified from Patrick Whitefield (2004)

farmer dependence on external inputs. Norman Uphoff (2003), a world leader in propagating the philosophy of sustainable agriculture, comments that SRI is a profound lesson for scientists, extension personnel, and farmers to remain open to new ideas. He further comments that not every proposed change in agricultural practice warrants undiluted attention. But if a possible innovation would have many benefits, it should be subjected to empirical rather than just logical tests, because our scientific knowledge is not (and never will be) perfect or complete. In the SRI instance, a paradigm shift was involved, one that is not yet fully understood and certainly not universally accepted.

1.15 A Dawning Realization of Ecological Agriculture

So far, we saw briefly how we humans made efforts to bring plants and animals under our control, how that need gradually developed into greed, how science and technology satiated that greed, and the major and serious consequences of that greedy action. We also saw, taking a set of specific examples, how some people began to think differently and how they interpreted the shades of difference between need and greed. Will it be ever possible for us to live in harmony with the remainder of the world, through cooperation, and not through conflicts?

To quote Rachel Carson (1963):

> Have we fallen into a mesmerized state that makes us accept as inevitable that which is inferior or detrimental, as though having lost the will or the vision to demand that which is good? Such thinking in the words of the ecologist Paul Shepard, 'idealises life with only its

> head out of water, inches above the limits of toleration of the corruption of its own environment … Why should we tolerate a diet of weak poisons, a home in insipid surroundings, a circle of acquaintances who are not quite our enemies, the noise of motors with just enough relief to prevent insanity? Who would want to live in a world which is just not quite fatal?' Yet such a world is pressed on us.

Modern agriculture has been a critical instrument in the dramatic transformation of the world and its environment. An industry that evolved primarily as a food production program in the last few decades has grown into a nature destruction program, simply because we are guided more by greed than by realistic need. Have we lost our perception of the land? And, have we forgotten that we humans were born out of the great land which patiently supports us and tolerates all our misdeeds? Have we unconsciously forgotten (or do we deliberately ignore) the call of Archie Roach to listen to the people and listen to the land?

Ecological thinking drives ecological agriculture. It seeks and calls for a change—a dramatic and significant one—in humans, which will value every organism with respect and regard. As long as we see every organism other than *Homo sapiens* as something meant for the service of human species, then we are inviting trouble. This may not occur in the immediate future, but in long run, it will. We, then, would need to think of mitigations and resolutions. Simply said, human arrogance as the most superior organism is the key cause for our problems today. Contentment and respect for the Earth as a whole is the sum and substance of ecological thinking, the axle of the wheel of ecological agriculture.

1.16 What Needs to Change?

Against this challenge, will it be possible for us to perceive, articulate, develop, evaluate, and apply an ecologically sound agricultural practice? Will it be ever possible for us to examine the implications of ecologically sound agriculture for landholders, farmers, and other stakeholders? The pure and applied scientists who practise as agronomists and soil scientists want to make agriculture a sustainable process by dealing with the scientific principles and the social dynamics that will underpin such a practice. The second group of people involved with agriculture are interested in managing change in the participants, market forces and mechanisms, incentive structures, and regulatory policies. We need to be clear that ecological agriculture is a complex system. It not only involves the biophysical elements such as soil, crops, animals, farming practices, and the intricate interactions among them, but also it needs to validate human knowledge, learning, institutions, and policies. The human factor cannot be modelled in a predictive sense, but because of what it is, it needs to be factored into the larger questions of societal renewal for a sustainable future. Consider these arguments by Röling and Jiggins (1998):

- The change to ecological agriculture is not only a question of sound scientific claims with respect to its appropriateness and feasibility, but especially also one of widely shared learning and social reconstruction of the environment.

- The change to ecologically sound farming is not only the outcome of technical intervention but especially also a negotiated outcome based on accommodation among paradigms, coalitions, institutional interests, and politics.
- Ecological agriculture will not be achieved by merely introducing different methods and technologies to individual farmers. A transformation of the entire soft system which can be called conventional agriculture is imperative, developing into an equally complex, but different soft system which can be called ecological agriculture.
- This transition requires a management of change that goes beyond providing policymakers with scenario studies based on computer simulation, in that it must forge ways forward which emerge from interaction among stakeholders, based on shared perspectives, shared ways of making visible the state of the environment, shared strategies, and collective decision-making.

Human effort, at least in the last two centuries, has been concentrating narrowly on maximizing the value of one target variable, such as crop yield, by manipulating a certain combination of variables present in the ecosystem. This effort has led to the partial destruction or total collapse of numerous ecosystems. It is impossible to control all the feedback loops. The environment is inherently unknowable and continuously changing. It cannot be suppressed to serve a limited goal. Hence an adaptive management strategy would be in order. The adaptive management strategy depends on flexible, diverse, and redundant regulation, monitoring for responsiveness, and experimental probing to appreciate and practise 'new' ways of perceiving the environment (Holling 1995).

What will be the characteristics of a general adoption of ecological agriculture?

- Farmers will recognize—that is understand and embrace—the idea of the farm as an ecosystem in itself and an integral component of the natural ecosystem.
- This simple, powerful proposition creates the thirst for a fuller understanding of the mystery of the living system of the farm. Farmers will seek to better understand and respect the role and functions of watersheds, biomes and biotopes, and landscapes, concepts that help explain the workings of the natural ecosystem, and factors that are part of the challenge of managing the farm ecosystem.
- As farmers reach a more complete understanding of the farm ecosystem, they will become progressively more critical of their current practices. They will seek ways to minimize external inputs to improve productivity. Instead, they will seek to maximize the natural capacity of the farm ecosystem to work in harmony with the vitality and fecundity of nature.

The most critical element in this process will be the need for each of us to let go the attitudes and convictions that are deeply embedded. From a value framework in which humans are considered the world's superior organism, mainly due to scientific skills and technological advancements, we need to see that we are an infinitesimally small part of the natural world. We need to accept that we have to shed our sense of superiority and learn with utmost modesty to live in harmony with the natural world and not in conflict. Such a realization is indeed hard to achieve, because we are guided by our selfishness and ego. In practical terms, we need to develop sensitivity and work towards achieving that realization. The shift to ecological agriculture coincides with or is predicated upon a shift from seeing everything around us as being individual or broken-down elements, to accepting everything around us as part of a larger, more complex whole. This is part of the Copernican Revolution which commenced with the realization that humans are not the centre of the universe, but rather a temporary and marginal event in an immense space. (Note: the thinking that fuelled the Copernican Revolution is now finding a fuller expression in the New Science—growing acceptance of multiple equivalent realities, as opposed to one solid objective truth, and of the inherent complexity of nature, as opposed to the certainty that knowledge can be accumulated about it.) Such a shift fits well with the shift from the arrogant focus on our efforts to monitor and control of nature to a realization that humankind is inherently part of nature (Tarnas 1991).

1.17 An Ecological 'Knowledge System'

One step towards achieving ecologically sound agriculture will be to accept the vitality of ecological knowledge. A potentially fruitful approach here is the knowledge system perspective, which looks at the 'institutional actors' within the arbitrary boundary of what can be considered a 'theatre of innovation', a drama capable of interpretation as a soft system. But how useful is this line of thought? One cannot say that such actors as research, extension, and farmers are a system. In all likelihood, they are not, in that there is no synergy among their potentially complementary contributions to innovative performance. Notwithstanding this problem, however, if we look at them as potentially forming a soft system, one starts to admit the possibility of facilitating their collaboration and hence the possibility of enhancing their synergy and innovative performance. Innovation is an emergent property of a soft system (Wilson and Morren 1990). Perhaps, it is premature to dismiss the knowledge system approach.

The following words of Funtowicz and Ravetz (1994) are worthy of reflection:

> The future looks less like the past than ever before and has in some ways become very threatening. As a species we are no longer guaranteed survival, even in the short term—and this is a consequence of our own doings, as collective humanity. We are living in a risk society.

1.18 Conclusion

The term 'sustainable development' refers to something more than simply growth; we talk of development here which is strikingly, subtly, and intricately different from growth. A change in the kind of growth is needed, a kind of development that is less material- and energy-intensive and more equitable in the distribution of its benefits. This emphasizes that changes are needed and that the security, well-being, and the survival of the planet depend on such changes (The Brundtland Commission 1987). However, some environmental activists reject the concept of sustainable development and even ESD as meaningless (ESD–Working Groups 1990–1994); they argue that these terms represent a way of thinking that seeks to find ways of allowing vested business interests to achieve their financial objectives. Sustainable development is not about giving priority to environmental concerns; it is about incorporating environmental assets into the economic system. Sustainable development encompasses the idea that the loss of environmental amenity can be substituted by wealth creation that placing a price tag on the environment will help us protect it unless degrading it is more profitable, that economic growth is necessary for environmental protection and therefore should take a priority over it. Sustainable development represents an adoption of the term sustainability, which once represented ideas of stability and equilibrium and harmony with nature. Sustainable development is an attempt to reduce the politics in decision-making by artificially replacing conflict with consensus, by emphasizing technocratic decision-making process such as cost–benefit analysis and economic instruments, and by ensuring environmental conflicts decided by the market.

At this juncture, it would not only be relevant but also be appropriate to refresh our minds with the visionary thoughts and words of Joseph Chelladurai Cornelius Kumarappa (JCK) (1892-1960), a committed and ardent disciple of Mahãtmã Gandhi. A couple of statements from JCK (1962), cited below, are adequate to kindle some refreshed thinking in us. On purpose, I will refrain from either elaborating or commenting on JCK's words, which squarely challenge Adam Smithian thinking and its consequence of technocentrism be it in agriculture or elsewhere:

> There is no such thing as the principles of Economics of Gandhiji. With Gandhiji, economics is a part of a way of life. There are no governing principles as are applied in the case of ordinary laws that have been enunciated in text books on Economics. Only two life principles govern all Gandhiji's economic, social, political and other considerations, viz. Truth and Non-violence. Anything that cannot be satisfactorily tested on these touch-stones, as it were, cannot be regarded as Gandhian. If a scheme of things leads to violence or necessitates untruth, then we may regard that as non-Gandhian. (p. 5)

> The agricultural economy which had been practised in our country in olden days is an instance of the enterprising economy. It is a self-sufficient economy. (p. 7)

> The American method of producing grains makes agriculture an industry as distinct from an occupation. We need to make that distinction clear because a great many of the differences that arise and the methods that are used and the principles followed come out of that distinction. An industry is not concerned with the question whet her people are starving in India or

> in any part of the world, its sole concern is to maintain high prices. Human considerations do not prevail at all. All that is needed is keep down the supply so that the demand will put-up the prices. … Ours is an ancient land with a teeming population. Land requires time to recuperate between crops. The more we extract from the land the longer it takes to regain its fertility. Our methods of agriculture have, through the experience 0f centuries, reached a stage where production is balanced with its recuperative power. If we use the Mithaiwala methods[1] and attempt to exploit the land to the fullest extent by stimulating it, we shall be exhausting its fertility faster than its ability to regain itself and finally we shall be turning good cultivable soil into barren deserts. (p. 18)

Has the Mahãtmã said anything pertinent to sustainability, when that word never had the connotation and usage, as it presently has? Mahãtmã Gandhi's primary concern was to alleviate poverty in India. He was clearly a human-centred person. He was all the time concerned about the poorest Indian living in the remotest India (Lal 2000). Yet, while thinking of wholesome and worthwhile paradigms to improve the lot of that Indian, he drew generously from nature, which, to him, was plentiful and bountiful. In 1909 he envisioned that an insatiable and unending pursuit of wealth accruing—and its derivative material benefits—that predominated the Western culture is a key threat to the Earth and natural materials. He forewarned how much such an imprudent lifestyle can bring about destruction to nature. By his remarks on freedom, self-reliance, and personal physical effort, he reiterated his recognition of nature and its vastness.

Ecological thinking and its derivative ecological agriculture are practices that spin around simplicity and modesty. Aggressive dollar-driven thinking has no place. Climate change for example is an issue created by us humans because of our badly thought-out and hasty, changed practices of land use (Stabinsky and Ching 2012). If we realize this weakness and remedy it, then we still have hope to leave a cleaner and better world for later generations of humans as well as other organisms, which are as important as *H. sapiens*! We are in a crazily fast era. We think that speed and rapid turnarounds of events are the norms of today. Is speed the root cause of present-day ecological–environmental malady, which has pushed us to think of sustainability (Raman 2013b)? I have no answers.

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[1] In page 13 of this monograph, JCK clarifies what he means by Mithaiwala economics and the alternative he suggests as the mother's method. According to him, the Mithaiwala economics creates false standards and violence, while the mother's method of production develops her love and truthfulness, but entails hard work.

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