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Man and plants: a relationship in crisis

Résumé

Each one of the astounding number of diverse species which make up the flora of the planet, is adapted to fill a niche in the apparently endless range of earth's habitats. Within each species there is a finer degree of adaptation of populations to smaller differences between essentially similar habitats. These adapted populations within species are known as ecotypes. They, and the associated assembly of ecotypes of other species which live in the same habitat, constitute an ecosystem. Ecosystems are subject to change over time. Change within ecosystems is a normal event in the natural world. Its main causes are changes in the climate and other components of the environment. Plants have the means to respond to slow natural changes through the production in every generation of individuals with genes in new combinations and hence with different ecological preferences. The source of new genetic variation is mutation – permanent, heritable changes in genes and their function – and the mechanism for creating new combinations is sexual reproduction.

If species are able to adapt, they survive; if not they perish, and this has been the fate of innumerable species in the past. Yet for many others their responsiveness to environmental change has been adequate, at least until recently. For the past two to three thousand years the rate of environmental change has progressively increased due to the human population explosion and to the increasing exploitation of the natural world through industrialisation and agricultural development. In many areas, plant populations are no longer able to cope with the rate of change and are disappearing. Humans, for long ignorant or uncaring about their destructive exploitation of the environment, have recently begun to show concern about the consequences of past and present follies, because of the dawning

realisation of their threat to the biosphere, in general, and to people, in particular. There is a growing awareness of the need for remedial action, which is expressed as conservation activities of different kinds, and most recently as the first attempts to plan strategies for coupling development to the sustainable use of natural resources.

The purpose of this book is to consider in detail one part of the conservation movement, namely the conservation of the genetic diversity of crop plants, a resource which is essential in the adaptation of crops through plant breeding to meet the changing needs of future generations.

Wild plants and plant communities are constantly changing

The seemingly endless variety of living things, plants and animals and micro-organisms, live together in characteristic communities of particular species – ecosystems – and not in random mixtures of species which occupy the same area by chance. The component species of an ecosystem are different in different habitats. The species interact, competitively, with each other and react to their physical environment – the temperature, rainfall, daylength, light intensity and soil type of the habitat – to form a dynamic community of immense complexity which is adapted to survival in that habitat. Ecosystems evolve through successive stages towards a final climax association of species which is relatively stable. However, even the climax community is in a state of dynamic equilibrium, and is liable to change in the long term.

There are two primary causes of instability in ecosystems; changes in climate and changes in human activities. Instability of climate due to long-term directional weather changes is seen in dramatic form in the advance and retreat of the polar ice sheets. The systematic accumulation of weather data in the past fifty to one hundred years and the recent development of methods to estimate the climate of past ages, have begun to quantify what previously had been inferred from anecdotal evidence, namely that climatic changes are normal, that they occur in short and long-term cycles, and that they differ in degree and extent across the globe.

Plant communities have responded to these environmental cycles. The response has occurred with change at three levels: the succession of one ecosystem by another, the substitution of one species for another within an ecosystem and changes in the genetic constitution of the individuals within a species. Generally, change will occur in all of these ways, resulting in the extinction of some species, the emergence of new ones, and in changes in the species composition of communities as well as in their geographical distributions.

We can read the sequences of past vegetation changes from the pollen profiles present in peat bogs and in alluvial sediments. Remains of larger fossils have also enabled scientists to paint the moving picture of vegetation change of past times. This provides a broad-brush picture of successional changes in plant communities. Recent scientific developments in the isolation and analysis of DNA from preserved plant remains indicate the future possibility of comparing the detailed genetic composition of modern with ancient ancestral plants.

The second cause of change, human activity, has the potential for inducing changes which are sudden and irreversible. Large-scale deforestation to provide land for agriculture and wood for fuel, intensive grazing by flocks of domesticated animals, which prevents the regeneration of forest and shrub communities through the destruction of their seedlings, and industrial development and urbanisation, have all had dramatic and directly destructive effects on natural ecosystems. In addition, man has caused equally profound indirect effects through environmental pollution from industrial and urban development. Some of these can rapidly change or destroy communities, such as the general pollution by heavy metals of the water, soil and atmosphere around the sites of heavy manufacturing industry, but others are insidious, cumulative and slower to appear. A notable example of the latter is the much publicised 'greenhouse effect', in which rising levels of atmospheric carbon dioxide, methane and other gases are thought to be the cause of a progressive rise in atmospheric temperature. The full effects of this temperature rise on climate, sea levels, ocean currents and of course on vegetation, have yet to be determined.

It has always been a feature of life on this planet that plant and animal species have had to adapt to changing environments and survival has depended on their ability to do so. The new factor in this dynamic relationship between plants and their environment is the greatly accelerated rate of change imposed by man, with which the response mechanisms of plants are unable to cope, resulting in the large-scale losses, not only of species but also of whole ecosystems.

Genetic variation and sex are the keys to adaptive change

The characteristics of plants are determined by the genes located in their DNA. The expression of many of these genes is subject to the influence of the environment, and so plant characteristics are generally thought of as the result of gene and environment interaction. Genes are themselves subject to constant – though infrequent – changes due to events which are both external (e.g. irradiation) and internal (e.g. errors in the replication

and repair of DNA). These random changes in the linear code of the DNA, affect its activity and produce the variation in the form and function of the plant on which adaptation depends. Organisms evolve with new potentialities and attributes which differ in their fitness under the selection pressures of a particular environment.

One attribute which developed early in the evolution of plants and which has since been universally conserved, is the ability to exchange genetic material among individuals. In higher plants, the mechanism of exchange – sexual reproduction – takes many forms, often of great complexity. The widespread occurrence of sexual reproduction in the living world, coupled often with the development of elaborate genetic mechanisms to control the degree of relationship of the mating individuals, is a clear indication of its importance to adaptation, evolution and survival of the species.

Sexual reproduction ensures the spread and mixing of genetic variation within the group of individuals which exchange genes. The consequence is that, in each generation, all individuals differ in their genetic potential and hence their fitness to the environment. Some will be better adapted than others and will leave more progeny. These progeny, in turn, will go through the same process of genetic reassortment when they in turn reproduce.

The normal state of affairs is of plant populations in a state of constant genetic flux, where individuals of different fitness interact with each other and with a physical world, which itself is subject to short and long-term change. If the generation of new forms with suitable attributes is adequate, then survival of the species is possible in the changing world. If it is not then species die out. Clearly, in this interaction between genetic systems and changing environmental pressures, the rate of change of the environment and the rate of genetic response of the species, are critical to survival.

Natural ecosystems are being destroyed by human population increase and industrialisation

Rates of change in the living world are accelerating, due to the progressive disruption of ecosystems by human activity. Adaptive responses, which are necessary for the survival of wild species, are dependent on an adequate reserve of genetic variability. The same is true for the adaptation of crop plants to present and future needs.

However, the possibilities of achieving the necessary adaptive changes are being reduced by the erosion, by human activity, of genetic variability. This is happening directly, through the large-scale destruction of plant communities, and indirectly through man-induced climatic changes lead-

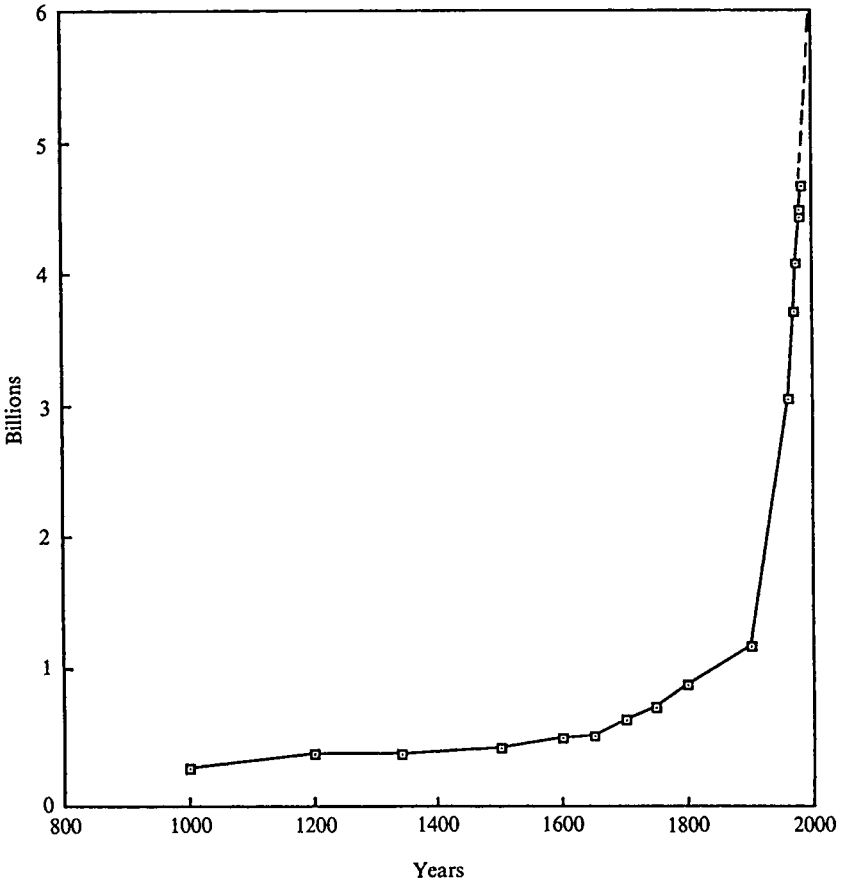

Fig. 1.1 Estimates of world population from AD 1000 to 1983 and extrapolated to the year 2000. (Data from Clark, 1967), and FAO, 1984.)

ing to, for example, the spread of deserts into hitherto semi-arid regions. In agriculture, it is happening at a headlong rate as a consequence of the recent practice of substituting genetically uniform high-yielding varieties, for the ancient and highly variable agro-ecotypes or landraces, on which agriculture has for so long depended.

Man has always been an integral part of the natural ecosystems of the planet, and until recently has lived as a harmonious part of these systems. It is only in the past 200 years, or so, with the deadly combination of runaway increases in population (Fig. 1.1) and poverty and in the ruthless exploitation of the natural resources of the planet, that this harmonious relationship has been destroyed. It has been estimated that when agriculture first developed, the total world population was of the order of ten

million (Clark, 1967). Today it is approaching six billion, and increasing rapidly, particularly in the developing countries of Latin America, Africa and Asia.

In the face of pressures for food, water and shelter for these billions of people, of the remorseless demands for raw materials for industry and the associated pollution of the environment, all of our ecosystems are at serious risk.

Public awareness of environmental destruction is growing

Concern about man's degradation of the environment is not new. It has a long and distinguished history which may be traced back in Western thought to the times of classical Greece. For example, fears of widespread man-induced climatic change, often thought to be of recent origin, may be traced back to the writings of Theophrastus, which apparently prompted the forest conservation policies of some British colonial countries (Grove, 1990).

In the 17th and 18th centuries, environmental concerns developed in association with, and as a result of, the colonisation of the world by Europeans and particularly as a result of the growing awareness, among a more thoughtful minority of those involved, of the destructive impact of European development on the environments and peoples of the newly colonised lands. In general, colonisation was regarded as a kind of cultural evangelism, and the exploitation of the natural resources of the subjugate lands was thought of as a natural reward for the civilising benefits which were provided. Rare criticism of development practices came usually from scientists and particularly from ecologists who studied the origins and composition of ecosystems. It goes without saying that these criticisms, published in specialist scientific journals and usually couched in objective, restrained prose, rarely travelled beyond the community of professional biologists and did little to awake public concern to the damage being done or to its implications for the future.

The movement of environmental issues from the specialist concerns of a few scientists to a centre-stage focus of general public concern, is a recent event attributable to three causes. The first is the writings of a few inspired and passionate scientists with the gift of riveting the attention of the literate layman. For example, Rachel Carson's *Silent Spring* (1962) was enormously influential and was the first introduction of many people to environmental issues. At the same time, the mass media began to appreciate the significance of environmental issues to people and an increasing output of

stories in newspapers, on radio and notably on television has been the result. For example, in 1970, the *New York Times* published 150 general articles on environmental issues, 650 on air pollution and 900 on water pollution (Holdgate, 1990).

The second cause is the sequence of environmental disasters which has occurred in the past thirty years or so and which includes the sinking of the *Torrey Canyon* and *Exxon Valdez*, Bhopal, Three Mile Island, Chernobyl, the desertification of sub-Saharan Africa, the repetitive inundation of Bangladesh and the burning of the Amazonian rain-forest; all have been brought vividly to the attention of the world by means of television.

The third reason why the general public is now aware of environmental issues is the effective and often unorthodox activities of committed pressure groups such as Greenpeace and Friends of the Earth. Both seek the active support of concerned citizens in policies which are science based and often tactically implemented by acts of considerable courage which inevitably attract media attention.

In view of this comprehensive publicity, it is fair to say that no one who has access to the mass media can be unaware that we are faced with terrible threats to the global environment and hence to ourselves. Changes in climatic and hence vegetational patterns are already under way. Where they will lead is a matter of intense debate, but it is clear that plants will have to adapt to survive and this principle applies equally to our cultivated plants.

In the 1960s, the International Council of Scientific Unions founded the International Biological Programme (IBP). Its aim was to understand through the synthesis of existing knowledge and through research, the basic processes which support life on the planet, as a means to solving problems of human welfare. One of the sub-programmes of the IBP was concerned with plant genetic resources and one of its activities, jointly with the Food and Agriculture Organisation of the United Nations (FAO), was to hold a technical conference in 1967. Its outcome was the landmark publication *Genetic Resources in Plants – Their Exploration and Conservation* (Frankel and Bennett, 1970), which assembled current knowledge and synthesised ideas on the subject. It helped focus the attention of the scientific community but sadly had little impact in the wider world; a good illustration of the difficulty of communication between scientific specialists and the general public.

The Stockholm Conference on The Human Environment in 1972 was a milestone in stimulating the awareness of governments and policy-formers of the scale and consequences of environmental degradation.

In 1980 a World Conservation Strategy was launched by the International Union for the Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP). The idea that all ecological systems were interdependent, began to receive general recognition in the concept that there is but a single biosphere for the planet. This global biosphere has many levels of organisation and Man-induced changes in one system or one place, can have consequences for other systems in other places. For example, the recent change in the annual movement pattern of El Nino, the cold Pacific current, has not only disturbed the anchovy fisheries of Chile and Peru, and the economies of these two countries but, it is now becoming clear, is influencing the climate of other parts of the world.

In 1983, the UN General Assembly set up the World Commission on Environment and Development to address the joint issues of environmental conservation and sustainable development. Its comprehensive report – *Our Common Future* (1987) – breaks new ground in setting out in detail the objective of integrating the alleviation of world poverty with world environmental protection. It is not too much to say that it is now widely recognised that the reconciliation of these aims which traditionally have been mutually exclusive, is the greatest challenge facing mankind.

The prospect is daunting but there are some encouraging signs. For the first time, people are beginning to see themselves as a species with a unique and central role and responsibility in the biosphere and to realise that their selfish manipulation and exploitation of parts of it have profound consequences for the whole and for their own posterity. Happily, an increasing proportion of the general public, and, through it, of governments, is beginning to accept this responsibility and with it the idea that the natural world is not an enemy to be subdued nor a resource provided for our indiscriminate exploitation but rather a partner whose survival is essential to our own.

The problem in an issue of such complexity, is how to turn concern into effective action. One of the obstacles to progress is the gulf which exists between the level at which principles are formulated and internationally accepted, such as those defined in *Our Common Future*, and the level at which they are translated into actions by the industrialists, farmers and foresters of our societies. In the final analysis, changes are dependent on the actions of individuals who are struggling to maintain or improve their standard of living from within established economic and social structures. Few have the moral and financial independence to step alone outside the system, and initiatives must come from elsewhere.

Action plans, if they are to succeed in changing the direction and

momentum of established systems, need to be widely accepted, securely founded on reason rather than emotion, and based on adequate scientific and technological information. All too often these elements are lacking. For example, few countries have reliable weather data for as recently as one hundred years ago, and even fewer have completed inventories of plant species or detailed systematic surveys of the composition of the ecosystems within their borders. Consequently, assessment of the significance of present trends and predictions of their future consequences are fraught with uncertainties.

It is clear that the protection of the environment and the conservation of its resources is not a matter for unilateral action by national governments. The solution to environmental problems will require a level of international cooperation hitherto unknown in world affairs. It is important to stress that despite the magnitude of the problems this is not a Doomsday scenario. There are very encouraging indications that nations recognise the need and have the will to organise a collective change of direction towards sustainable development. MacNeill (1990) stresses the central role of the United Nations in all of this and refers to suggestions for a UN Environment Council, equal in authority to the Security Council and known perhaps as the Earth Council.

Genetic diversity of crop plants is at risk

In this book we are concerned with one component of the man-induced changes to the biosphere, the destruction of the genetic diversity of our crop plants. The pressures of agricultural and industrial development in the past hundred years have been so powerful and the consequent changes so rapid, that the only effective response to crisis has been to collect and conserve – usually as seeds in a cold store – representative samples of crop diversity. This collecting, which began on a small scale and in an uncoordinated way in the 1920s and 1930s, long before the conservation of the wider environment became a matter of international concern, developed after 1974 into an urgent large-scale operation for rescuing the diversity of all major crops.

We intend to show why it is important to conserve the genetic resources of our crops, that this work is grounded on science, that it has great economic implications, and that it is essential to food security in a changing world and not least in relation to sustainable development. We will show what has been achieved already, what remains as a challenge for the future and how this challenge may best be met. We attempt to sum up the present

status of all aspects of crop genetic resources conservation from the standpoint of its science base and operational effectiveness.

The experience gained in the last fifteen years of urgent rescue collecting has provided many lessons in cost-effectiveness in the planning and execution of genetic resources conservation and in forming cooperative links between people of disparate interests. Three general principles emerge:

- The need for planning and for operational decisions to be based on prior analysis of existing data rather than on inspired intuition.
- The need for the focus of activity to be the crop species or species group rather than the country or region.
- The essential need for active international collaboration.

Finally, we confidently predict that the knowledge gained from collecting and conserving crops and their wild and weedy relatives will often be relevant to the conservation of other plant species.