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Development: Sustainability and Physical Geography

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Definition

'Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987: 8, or more commonly known as the Brundtland Report). This quote is the standard starting point for understanding sustainable development. Within this context, the physical environment tends to be viewed as a fragile entity that requires careful management. Concepts such as 'carrying capacity', 'ecological footprint' and 'natural capital' reflect this view of the physical environment as in need of stewardship. Physical geographers have contributed towards sustainable development by establishing baselines from which change can be assessed, by identifying the thresholds and equilibria of the physical environment and by providing an insight into the complexity that locality and scale have on the sustainability of the physical environment.

INTRODUCTION

Sustainable development has emerged as a key issue in policy at national and international levels. Although the concept is often expressed in terms of economics and culture, the concept originated and is firmly based within the physical environment. Views of the physical environment and of how humanity should use or develop it have not been constant and these changing views have greatly affected environmental policies. Early concerns with environmental degradation can be traced back to figures such Evelyn (1661), who wrote about smoke pollution in London and even offered an environmentally sustainable solution of planting trees to ameliorate the problem. Marsh (1864) and Thomas (1956) expressed more contemporary concerns identifying a fragile and interconnected physical environment at risk of destruction through human activities. Such environmental concerns among academics and the intelligentsia should not be taken as indicative of a general view of the nature of the physical environment. In late nineteenth-century North America, for example, the physical environment was seen as an hostile enemy that required taming by human intervention rather than a fragile entity requiring protection.

Concern for the physical environment in the late nineteenth and early twentieth centuries found form in policies such as the development of national parks in the Untied States and national and international conservation movements, such as the World Wildlife Fund (WWF). Policies were often driven by concerns that seem odd to modern eyes. Establishing Yosemite as the first national park in the USA, for example, was a project that relied heavily upon the determination and connections of John Muir, a champion of the concept of wilderness (Wolfe, 1945; Sargent, 1971), and the representation of the park landscape as a commodity. Uniqueness was seen as being translatable into money and also national pride. Congress heard how vast sums were spent overseas by Americans visiting wilderness areas in Europe such as Switzerland and how American areas could boast greater scenic beauty than their European counterparts (Runte, 1997). Often, policies revolved around the conservation of 'unique' features, such as the Grand Canyon, ably championed by President Roosevelt, or individual species, such as the panda, the symbol of the WWF. A view of the physical environment as an integrated whole may have been gaining currency in academic circles, but it failed to provide an emotive imperative for policy.

Speeding forwards to the late 1960s, a more organized and holistic view of the physical environment started to infiltrate policy-making. *The Limits to Growth* (Meadows et al., 1972), a report from the Club of Rome, presents the environment as a finite resource that requires management to ensure that the physical limits to development that it imposes are not exceeded. The authors modelled the world as a global system in terms of the interaction of a few key parameters. From this modelling approach they were able to show that contemporary activities would soon exhaust the finite resources available. Concepts derived from such analysis, including carrying capacity, became key tools for investigating the ability of this finite physical environment to sustain life. Viewing the physical environment as a finite resource shifted policy emphasis from taming to maintaining. Instead of exploitation, policy has increasingly been couched in terms of balance and stability. The physical environment is increasingly seen as a fragile entity that needs protection from the excesses of humanity – a near role reversal from the nineteenth century. It is within this framework of changing perceptions of the nature of the physical environment that physical geographers have contributed to monitoring and understanding sustainable development.

SUSTAINABLE DEVELOPMENT

Although many discussions of sustainable development begin with the quote from Brundtland (above), there is no consensus definition of what sustainable development is (Adams, 2001; Kates et al., 2001; Kates et al., 2005). Sustainable development has become an ongoing dialogue rather than a fixed entity. There may be a set of guiding principles at the heart of the concept but these too have evolved as the different actors, networks and negotiations have changed. The definition of sustainable development depends on what you believe should be developed (society, people or the economy) and the emphasis you place on the nature of sustainability (as a set of goals, measurements, values or practices). This diverse conceptualization of sustainable development permits both 'light' and 'dark' green activists (see Chapter 18) as well as more conservative economists to buy into, and pledge allegiance to, sustainable development. As Kates et al. (2005: 19) noted:

> One of the successes of sustainable development has been its ability to serve as a grand compromise between those who are principally concerned with nature and environment, those who value economic development, and those who are dedicated to improving the human conditions. At the core the compromise is the inseparability of environment and development.

Official definitions of sustainable development and its basic principles have evolved. From the initial stewardship perspective of the Club of Rome, there has been, through the Brundtland Report, the Rio Declaration (UNCED, 1992; Parson and Hass, 1992) and the Johannesburg Declaration (2002), increasing recognition of the importance of the multitude of links between human institutions and the physical environment. Coupled with this recognition has been the growing prominence of the view of the physical environment as an increasingly frail and fragile resource that requires human institutions to ensure its survival.

From the perspective of physical geography, sustainability has focused on assessing actions as reversible or irreversible within a temporal scale that is limited to a few generations. Within this time frame, geological processes and patterns, such as species evolution and extinction, are neglected while relatively rapid changes are highlighted as significant. This produces a view of the physical environment that is defined by anthropogenic disturbances rather than biophysical processes for which human intervention is a relatively insignificant factor. When large, geological processes become manifest, as with the tsunami on Boxing Day 2004, humanity is jolted back to a view of the physical environment as hostile and unpredictable.

Within the 'grand compromise' of sustainable development (Kates et al., 2005) physical geography and physical geographers have a large role to play. The nature of this role varies depending on the view of the physical environment employed and the emphasis given to the different aspects of sustainable development.

THE PHYSICAL ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

The Brundtland Report (WCED, 1987: 8) also commented on the importance of the physical environment for sustainable development:

> The concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.

The concept of absolute limits is reminiscent of *The Limits to Growth* (Meadows et al., 1972) and the concept of a carrying capacity for an area or volume. The Brundtland Report takes the concept of carrying capacity further by emphasizing the relative nature of these limits. 'Natural' limits to development do not necessarily exist but are defined in terms of a balance or emergent relationship between social and technological capabilities and the natural capacity for absorbing change. Such a concept retains a distinction between 'natural' and 'human' but does highlight the interactive role of the two in defining limits. Indeed, the Brundtland Report highlights that the two – environment and development – are inseparable. This approach to sustainability implies, however, a relatively, but not infinitely, malleable physical environment. That is, the environment is viewed as at once fragile and in need of human protection but also sufficiently robust to undergo regeneration if adequate guardianship is applied. Scientific analysis, and by extension physical geography, has a clear role in identifying the limits beyond which this regenerative capacity dissipates and in understanding how different scenarios of use interact with the physical processes that set the limits and affect regeneration.

Goudie (2000) notes that human impact can be expressed by the formula:

$$I = PAT$$

where I is the amount of pressure or human impact, P is the population, A is the level of affluence or resource demand made by the population and T is a technological factor. This set of interrelated factors can influence the carrying capacity of an area (Figure 22.1). An area or region will have a limit to the population it can maintain but this level need not be constant. For example, changing levels of affluence may mean that demand for resources increases. Similarly, technological advances, such as a switch from coal to nuclear power electricity generation, for example, changes the nature of the resources required. This not only influences the demand for coal, but also affects the nature of pollution in an area and so indirectly influences carrying capacity. Technological changes can also alter the efficiency of resource use, thereby increasing the carrying capacity of an area. The interplay between the three factors means that carrying capacity is a rather fluid property. It is also important to bear in mind that resources and the effects of resource use are not necessarily confined by political boundaries: resources and pollution can be imported and exported.

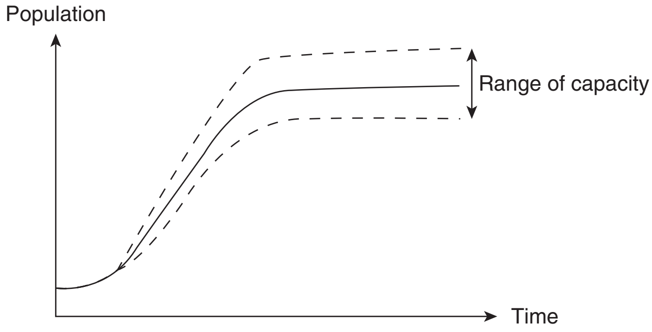

Figure 22.1 Carrying capacity and rande of carrying capacity

Ecological footprints and carbon footprints are outcomes of the view that the physical environment is a separate entity under stress. Human activities create a quantifiable impact on a fragile physical environment. These activities can be graded in terms of their impact and so appropriate management strategies employed to ensure that the overall impact of the individual, organization or society is reduced. These concepts are useful tools for extending the understanding of the sensitivity and absorptive capacity of the physical environment and in making abstract concepts comprehensible to individuals and organizations. Likewise, and as important, is the translation of this quantity into a management device for auditing the success or failure of schemes designed to reduce such impacts.

Concepts in sustainable development have also built upon the ideas of environmental economics such as suggested by Pearce et al. (1989) in *Blueprint for a Green Economy* and Pearce (1995) in *Blueprint 4*. Environmental economics uses the concept of maximizing income while maintaining the stock, assets or capital. Environmental economics divides this capital into two types: human-made and natural capital. Natural capital is created by biogeophysical processes and represents the ability of the physical environment to meet human needs. These needs can include the provision of biophysical 'services' that maintain a fit environment for human habitation such as biophysical processes that maintain the capacity of wetlands to absorb pollution. Within environmental economics natural capital has to be converted into a monetary value to allow it to be compared, traded and substituted with other types of capital. Putting a value on natural capital suggests the potential for losing natural capital in some activities while gaining it in others. Maintaining the overall capital of the natural environment implies that human-made capital could replace natural capital in some circumstance where human-made capital provides the same functions (Beckerman, 1995). Although human-made capital may not be able to replace the functions of natural capital in some circumstance, the application of the concept implies that some destruction of the natural environment may be acceptable in economic terms (Barbier et al., 1990; Daly, 1994).

Figure 22.2 illustrates the relationship between natural and human-made capital. Although total capital remains at the same level, the proportion of natural

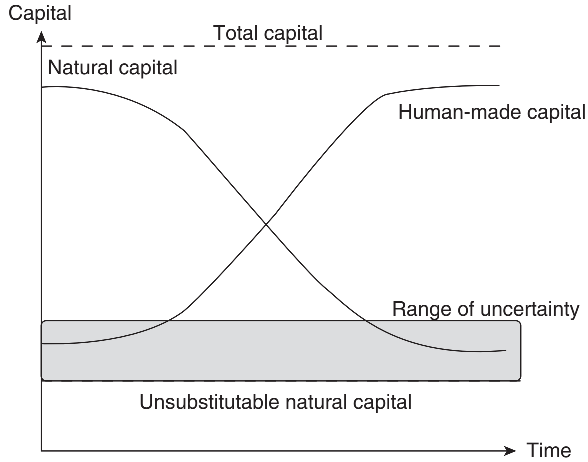

Figure 22.2 Relationship between total captial, natural capital, human-made capital and unsubstitutable natural capital

and human-made capital can alter. There is, however, a lower limit below which natural capital cannot fall. This represents unsubstitutable natural capital, both that part of natural capital for which there is no equivalent human-made capital and a proportion that could be substituted but which if removed would reduce natural capital below a level at which it could reproduce itself. The nature of each curve, its steepness and exact shape, will vary with location and with the factors identified by Goudie (2000) noted above. The range of uncertainty concerning the level and nature of the unsubstitutable portion of natural capital means that a key role for physical geography lies in identifying and understanding the nature of this uncertainty.

Similarly, ecological economics focuses on the links between human and ecological systems and their feedbacks, and tries to merge socio-economic and environmental systems into an holistic entity. It aims to provide practical policies for sustainable development (Berkes and Folke et al., 1994; Berkes and Folke, 1994, 1998). Within this framework, policy is designed to maintain development activities within the 'ecological Plimsoll line', a condition that represents the range of scientific uncertainty about environmental limits, including uncertainty associated with human impacts. According to these theories, development is acceptable for as long as the demands of human activity on the physical environment fall within this zone of uncertainty.

MONITORING, MODELLING AND MANAGEMENT

Pitman (2005) suggests that physical geographers can usefully aid Earth System Science (see below) by improving the scientific understanding of biophysical processes and so provide climatic modellers, for example, with information on the spatial variation of key parameters. Physical geography, however, is much more than a 'little helper' for climate modelling. The discipline has sought to understand the biophysical components of the earth, especially those systems in the near-surface realm (biosphere, geosphere, atmosphere, hydrosphere, cryosphere, etc.), and their process linkages across a large range of spatial and temporal scales.

In turn, physical geographers have made substantial contributions to sustainable development by providing understanding about the nature of the physical environment and how it changes. They have helped to identify the current state of the earth's biophysical system, but also how it changes in space and time and the nature of the limits to that change. Contributions therefore include:

- establishing baselines from which change can be measured
- revealing the nature of past environments and explaining how and why environments have changed through time at particular places
- identifying and explaining differences in temporal and spatial sensitivity to change
- exploring the impact of natural and anthropogenic changes on biophysical systems, often using modelling approaches.

Identifying and mapping the current state of the physical environment is a vital initial step in establishing how close to 'limits' the current environment is. Once a baseline has been identified and represented in an appropriate manner, then changes from the baseline can be monitored. Monitoring change is the second major contribution of physical geography. Physical geographers are trained to use techniques that are useful at very small scales and at very large scales, from remote sensing to *in situ* monitoring using nanoprobes.

The broad range of scales over which environmental processes operate is matched by the ability of physical geographers to integrate techniques from a range of scales to understand a problem. Importantly, physical geographers tend to study the physical environment in all of its complexity, taking into account both general, process laws and the role of factors that are place- and time-specific. That is, geographers are trained to consider both the immanent and configurational elements of scientific explanation, respectively (see Simpson, 1963). Fieldwork and field-based measurements are central to physical geography. This means that physical geographers are well aware of the need to translate often vague and difficult ideas into something that can be identified and measured in the real world (Lane, 2001; Inkpen, 2005). Such an ability is an important skill when dealing with the complexity of the physical environment.

Monitoring of the physical environment needs to be selective both to conserve resources and to enable effective data analysis. Physical geographers understand the spatial and temporal variability and sensitivity of the physical environment. This means that they are able to identify and study areas where the responses to the impact of human activities are likely to be greatest. Pepin and Siedel (2005), for example, found that the ratio of modelled air temperature to recorded surface temperature at high altitude sites is highly sensitive to the local topography. Similarly, Pepin and Duane (2007) found that the disparity was increased by incised topography. Understanding this local relationship and its geomorphological controls is important for modelling the potential impact of climate change in high altitude areas.

Physical geographers have also provided a context within which contemporary changes in the physical environment can be assessed. Environmental reconstruction can identify environmental change in the past and the potential triggers for it. Rates of change can be correlated with changes in external stimuli or changes inherent within a system. Rates of change can be used as a guide for the impact of current trends in key parameters, although the past is not necessarily an accurate guide to the future state of a physical system, as Lioubimetseva (2004) notes in relation to arid and semi-arid areas. Goudie (1995) notes that measuring rates of change in the physical environment is difficult because studies are often restricted by the spatial area they can monitor and by the time spans available for monitoring. This often means that areas of different size and characteristics are compared when data are amalgamated. Similarly, he notes that the extrapolation of short-term rates to predict long-term change is fraught with problems, particularly problems concerning relating rates across different spatial scales and comparing change that is episodic, and therefore likely to be rare in monitoring records, with change that is continuous.

Physical geographers have developed concepts that reflect the spatial and temporal complexity of the response of the physical environment. The inherent tendency for physical systems to undergo rapid adjustment as forcing conditions change or thresholds are crossed can be an important system property to identify as this type of change can be mistaken for the result of external stimuli such as climate change. Landscape sensitivity (Brunsden and Thornes, 1979; Brunsden, 2001), for example, aids the researcher in identifying system properties that will resist the impact of external stimuli, such as system structure, coupling efficiency and resilience. Likewise, these concepts help the researcher to understand the complexity of response of the landscape through, for example, divergent pathways of development, connectivity and decoupling.

Slaymaker (2007) illustrates how concepts derived from physical geography can be applied to issues of sustainable development in the context of the MANRECUR project. This project looks at sustainable development in a small Andean watershed in Ecuador, the El Angel River basin. He notes that priority tends to be placed on short-term objectives of sustainability while the geomorphologist might legitimately ask questions concerning sustainability over longer timescales more appropriate for the operation of geomorphological processes.

The role of physical geography in the implementation of sustainable development can be further illustrated using the case study of Hillman and Brierley (2005) and their review of catchment-scale stream rehabilitation. They identify two paradigms to river management: the engineering paradigm and the repair paradigm (see also Downs and Gregory, 2004). The engineering paradigm focuses on a reductionist view of scientific management that understands the river from the principles of fluid dynamics and hydraulics. Solutions within this paradigm are evaluated against the fulfilment of a single objective, usually related to flow management and flood control. Channelization and other 'hard-engineering' methods are favoured responses because these increase the degree of control over hydraulic variables. In this approach to management, the river system's natural variability and complexity is viewed as a major impediment to its management. Within this paradigm expertise and knowledge lies with technical experts, including engineers; local understanding may be considered but there is a tendency to focus on fixing short-term problems using 'cook-book' solutions . If one set of engineering solutions fails, another set are tried creating a spiral of increasingly technologically 'advanced' solutions. This approach to river management was pervasive in many countries throughout much of the twentieth century but is increasingly being replaced by the repair paradigm. This takes a more holistic approach to river management, partly by changing the focus of study from the river to the whole catchment, thereby altering the spatial and temporal scale of phenomena that should be considered in management (Bravard et al., 1999; Brierly et al., 2002; Everard and Powell, 2002). Any management plan has multiple objectives concerned with the overall ecological 'health' of the catchment. Emphasis is on enhancing the 'natural' dynamics of the system to aid the recovery of the river rather than controlling the river to ensure its mechanical stability. Within this new paradigm, it is vital to identify and understand the pathways of sediment movement, the dynamics of this movement as well as the role of morphological diversity in supporting system resilience and recovery.

Within the repair paradigm, the human aspect is not neglected. Local and community participation is a key element in defining the objectives of any management project. Given the negotiated nature of sustainable development this is an important consideration. Hillman and Brierley (2005) note, however, that the scale at which geomorphic and ecological processes operate within a catchment might not necessarily be matched by the scale at which local communities and institutions act. This is a general problem with developing sustainable policies for the physical environment. The mismatch between the time and space scales relevant to the operation of biophysical systems and human institutions can produce lags and compromises in policy implementation that negate the original objectives of inclusiveness. Importantly, however, the setting of management objectives requires an understanding of the local and historical context to provide local communities with a feeling that the management goals are of relevance to them. This reduces the overarching acceptance of expert scientific knowledge as the only or final arbitrator of what is 'correct' management. Such a situation is full of difficulties and usually requires a lengthy process of negotiation and compromise to develop an acceptable framework for sustainable development for any specific project.

SUSTAINABILITY SCIENCE AND EARTH SYSTEM SCIENCE

Physical geographers have, as noted above, been concerned with the complexities of the physical environment in space and time, focusing on the local, on the context and thereby drawing out the complexity of place. Recently, there has been a movement towards developing a 'new' science based on upon the view that addressing problems of intergenerational equity requires a global perspective. Kates et al. (2001) highlight that this 'new' science, Sustainability Science, should allow an understanding of nature and society by focusing on the interaction between global sociological and ecological processes that are characteristic of particular places and sectors. Komiyama and Takeuchi (2006) suggest that this trend towards a global science is partly based in a perceived need for a science of sustainability that recognized the link between science and economy yet was free from the political basis that seemed to dog debates of sustainability at the global scale (Kates et al., 2001; ICSU, 2002; Clark and Dickson, 2003). While it is debatable if politically neutral studies are attainable (Demeritt, 1996, 2001; Cohen et al., 1998; Schneider, 2001), recognition that the global scale is an appropriate level of analysis is significant. Sustainability Science aims to pursue an holistic, transdisciplinary approach to identifying problems at the global scale in these systems and appropriate solutions for sustainability at this scale (Komiyama and Takeuchi, 2006; Swart et al., 2004).

Komiyama and Takeuchi (2006) identified two obstacles to developing such a science: the complexity and interconnectivity of the problem and the fragmentation or specialization of research, an issue echoed by Clifford (see Chapter 20). They suggest that overcoming these twin dilemmas requires knowledge structuring. Knowledge structuring involves the clarification of relationships between problems and then identifying or mapping not only the web of these relations but also the organization and mobilization of the various specialist fields to address the problems. This all-encompassing overview is to be achieved by developing a framework that produces objective and quantifiable criteria and indicators of sustainability that are capable of integration. At the same time, it is expected that the criteria and indicators developed will also be sensitive and flexible enough to recognize the cultural distinctiveness of communities and the need for differentiated solutions.

Clifford and Richards (2005) identify a similar trend towards Earth System Science (ESS) which, citing Pitman (2005: 138), 'is the study of the earth as a single, integrated physical and social system', which will provide solutions to major world problems by eschewing reductionist approaches. Clifford and Richards suggest that despite the avowedly holistic intentions, ESS has substantive reductionist tendencies. They also suggest that the all-inclusive nature of ESS means that there are no boundaries to its scope. The whole globe and presumably all of time is its subject-matter which means it is unclear how the spatial and temporal scales that are relevant to answering any scientific questions can be adequately defined. Clifford and Richards' apprehension concerning the dangers of trying to encompass the plurality and complexity of reality under one scientific enterprise can be equally applied to Sustainability Science. Both are prospects that run counter to the spatially and temporally complex image of the physical environment that physical geographers have been instrumental in identifying and explaining.

CONCLUSION

Definitions of sustainable development reflect the negotiated and evolving nature of the term and the actors involved in that ongoing debate. The physical environment has always played a central role in this debate. Initially, attitudes towards the environment as an hostile entity encouraged an exploitative approach to its use. Slowly, though academic publications and general awareness, the physical environment became seen increasingly as a fragile entity in need of care and protection from humanity. This attitude encouraged a managerial view of the physical environment which emphasized limits, the processes that control those limits and the human impact on them. This has influenced what is studied and the concepts used to understand and manage the physical environment.

Physical geography has, and is, making a valuable contribution to the sustainable development debate. Establishing reliable baselines that characterize the current state of the physical environment is an important starting point both for developing sustainable projects and for assessing their impacts. Similarly, monitoring how the physical environment changes and contextualizing this change historically are important aspects of physical geography. When physical geographers have focused on timescales of relevance to managers, their understanding of the local, complex and context-dependent nature of the physical environment have provided an antidote to the more homogenizing tendencies of global modelling. Applying concepts derived from physical geography, such as landscape sensitivity, have helped to instigate more holistic and place-sensitive, as well as sustainable, management practices. This appreciation of the importance of spatial and temporal complexity is increasingly threatened by the modelling- and technocratic-based research of Sustainability Science and Earth System Science.

SUMMARY

- Sustainable development is an evolving concept that is based on a set of negotiations between different groups.
- The physical environment tends to be viewed as a fragile entity requiring management or stewardship to protect it from human activities.
- Physical geography has contributed to this concept by establishing baselines from which to assess change, monitoring change in the physical environment and contextualizing it, by recognizing the appropriate nature and scale of system elements.
- Physical geographers understand that the physical environment and its responses are spatially and temporally complex and historically and contextually bound. This perspective is diluted in global modelling approaches such as Sustainability Science and Earth System Science.

Further Reading

The general literature on sustainable development is large and growing. Good starting points are Adams' (2001) ***Green Development,*** Elloitt's (2006) ***Sustainable Development*** and Sayer and Campbell's (2004) ***The Science of Sustainable Development***. For sources more explicitly concerned with physical geography, there are a number of project websites that provide a good indication of the role of physical geographers in applying and developing this concept. For river management, useful sites are: Grand River Conservation Authority (www.grandriver.ca/), Plan Loire Grand Nature (www.rrivernet.org/loire/), Mersey Basin Campaign (www.watersnorthwest.org), Murray–Darling Basin Commission (www.mdbc.gov.au/), the River Styles Framework in Australia (http://www.riverstyles.com/outline.php) and the Mekong River Commission (www.mrcmekong.org). For semi-arid environments, useful sites with examples or projects are: MEDALUS, an EU-funded project studying Mediterranean Desertification and Land Use, 1991–99 (www.medalus.demon.co.uk), RECONDES, an EU-funded project studying southeast Spain (www.port.ac.uk/research/recondes/), and Drylands Research, looking at research in Africa (http://www.drylandsresearch.org.uk/), the Department of the Environment, Water, Heritage and the Arts, Australia (www.environment.gov.au/), the United States Department of Agriculture, Agricultural Research Services (www.ars.usda.gov/research/) as well as similar agencies and departments in other countries.

Note: Full details of the above can be found in the references list below.

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