Soil science, population growth and food production: some historical developments

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> *"The peoples of the earth, whether they will it so or not, are bound together today by common interests and needs, the most basic of which are, of course, food supply and other primary living requirements. Those come, all of them, from nature and from nature alone – from the forests, the soils and the waterways."*
>
> Fairfield Osborn (1948)

Abstract

The world's population has doubled since 1960. Currently, the developing world accounts for about 95% of the population growth with Africa as the world's fastest growing continent. The growing population has many implications but most of all it requires an increase in agricultural production to meet food demand. Soil science has a long tradition of considering the growth in food production in relation to the increasing human population. This paper reviews some of the major developments in these subjects from a soil scientist's perspective. It starts with the work of Thomas Malthus and various subsequent studies relating population growth and food production. Population growth and projections up to the year 2050 are discussed. The main soil studies since the 1920s are reviewed with a focus on those conducted in the Dutch East Indies and the UK. The productivity of soil science measured by the number of publications and soil scientists has kept pace with the increasing population. Although the number of undernourished people in the world is on the decline, it is concluded that continued efforts from soil scientists remains needed particularly now the focus of attention in the USA and Western Europe moves from population growth *per se* to population ageing and obesity.

Key words: Environmentalism, food production, history, population growth, soil science, Thomas Malthus

Introduction [1]

Soil science is a relatively young science that emerged some 150 years ago. It developed in Europe, North America and the Russian Empire (Kellogg 1974). Soil surveys started in sparsely populated areas where there was ample land for farm extension and thus a clear need to for soil inventories (e.g. Russian Empire and the USA). In more densely populated Western Europe where land was relatively scarce, research efforts were devoted to maintain and improve soil conditions, and in most European countries soil survey organizations were only established after the Second World War. Soil science has always had a strong focus on increasing agricultural production needed for the increasing human population (van Baren et al. 2000).

[1] This is a modified version of chapter 2 in the book "Soil fertility decline in the tropics with case studies on plantations", by A.E. Hartemink (2003)

A. Bationo (eds.), Advances in Integrated Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities, 85–98.

One of the most intriguing global phenomena has been the increase in human population. This increase was most dramatic in the past 100 years and has been the cause for debate, which has resulted in a deeper understanding of man's role on earth. Much of the debate is related to food production and the environmental effects of increased land-use pressure due to the growing population. Over the years different views on the effects of a growing human population have been published and in this paper some of the main arguments are discussed including an overview of facts and figures. The aim of this paper is to provide a brief historical overview of studies on the relation between soil science, population growth and food production. Much has been written about these subjects and this paper is not aiming to review all available literature, but to summarize some of the major studies in order to sketch the main trends and developments. It starts at the end of the 18th century – which is some decades before soil science emerged.

Malthus and his followers

Thomas Malthus

In 1998, it was exactly 200 years ago since Reverend Thomas Malthus (1766–1834) wrote "An essay on the principle of population, as it effects the future improvement of Society". The stimulus for writing this polemic was his concern about the unwarranted euphoria of his colleagues who, in the aftermath of the French revolution, saw mankind progressing ever upwards to a world of universal abundance, peace and prosperity where all would be equal in health, wealth and happiness (Short 1998). He wished to demystify this utopian fantasy, and used his numeracy to point out a simple truth: Population, when unchecked, increases geometrically whereas subsistence increases arithmetically (Malthus 1826).

Malthus' theory on everlasting food shortages and poverty had three basic assumptions: (i) food was considered to be necessary for the existence of man and the sole limiting factor on human population growth, (ii) human population increases exponentially, and (iii) food production could only be increased linearly. His theory explained the scarcities and misery observed in England and he declared food paucity to be 'checks' to population growth imposed by the prescribed bounds of nature (Seidl and Tisdell 1999).

Malthus' assumption on exponential population growth was not entirely new and similar views were discussed in demographical research of the 17th and 18th century. His essay that was written in a brilliant way, facilitated the widespread acceptance of his theory. Initially he was abused as his essay was held for unholy, atheistic and subversive of social order (Bettany 1890). A major criticism is that the idea of exponential growth was deduced from growth in North America and it was not observed elsewhere at his time. Population growth in North America was mainly due to immigration, a confounding factor which was initially ignored by Malthus (Seidl and Tisdell 1999). In later editions of the book he slightly altered that view.

Malthus has been named founder of the social demographic discipline, but more importantly, he was one of the first who saw the importance of the environmental limiting factors on human material progress. His essay inaugurated a grand tradition of pessimistic environmentalism (Anon. 1997), which probably found its heydays in the 1960s and 1970s. Although many people in the 19th and beginning of the 20th century thought Malthus was right, he was wrong for he did not foresee the industrial age and the geometric effect of technology upon economic growth (Jensen 1978).

When C. Darwin read Malthus' essay in 1838 he saw the struggle for existence which inspired him for the "Origin of Species" published in 1859. There is thus a substantial influence of Malthus on the most influential biological theory (Bettany 1890; Seidl and Tisdell 1999).

The population bomb

After Darwin, the most renowned biologist and follower of Malthus is P. Ehrlich, who published in 1968 the book "The Population Bomb". The book became an instant best-seller and ran through several editions bearing slightly different names but the same message. Ehrlich's message was similar to Malthus: unchecked population growth will outstrip food production and destroy the earth's environment (Ehrlich 1968). The book contains a detailed and pessimistic account of what will happen when the population growth continues. Inevitably there will be mass starvation and the 3.5 million who starved to death (in 1968) would only be a handful compared to the numbers that will be starving in a decade or so in addition to the massive environmental degradation. In the foreword, Ehrlich states "In a book about population there is a temptation to stun the reader with an avalanche of statistics. I'll spare you most, but not all, of that". The few hard figures and projections given have not come out. For example, it was projected that there would be over seven billion people in 2000, a figure that was also used by the Club of Rome (there were six billion people in 2000), and the population in Calcutta would have reached 66 million by 2000, whereas the actual population in 2000 was around 11 million.

Ehrlich, being a scientist, included a small section in his book entitled "What if I'm wrong?" in which he states that the possibility exists that "…technology or a miraculous change in human behavior or a totally unanticipated miracle in some other form will save the day" (Ehrlich 1968). He found that highly unlikely but played it safe: "If I'm right we will save the world. If I'm wrong, people will be better fed, better housed, and happier, thanks to our efforts". Not a modest view and impossible to substantiate.

It is likely that Ehrlich's books inspired groups like the Club of Rome, which was formed and headed by the Fiat director A. Peccei. Their study "The Limits to Growth" which was published in 1972 entailed what would happen if economic growth and population growth continued. It had the following supposition: "The basic behaviour mode of the world system is exponential growth of population and capital, followed by collapse". A model was built to investigate five major trends of global concern: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of non-renewable resources and a deteriorating environment. Calculations were made by a team of the Massachusetts Institute of Technology and the results were shocking as most natural resources would be depleted within 100 year or sooner (Meadows et al. 1972). Moreover the study was pessimistic about the future of the land resources and advocated that the Green Revolution only caused widening inequalities and disruptions of stable societies. It is no exaggeration to note that "The Limits to Growth" study was momentous – partly as it was conducted by computer (so it had to be right) and initiated by an industrialist (a capitalist so not a person from the green movement). Despite the various predictions made in "The Limits to Growth", growth continued exponentially and many of the projections proved false with the comment on the increase of CO2 in relation to climate change as the most noteworthy exception.

A different sound from Malthus and his more or less faithful followers came from E. Boserup's study entitled "The conditions of agricultural growth" (Boserup 1965). Contrary to the common reasoning which is that the supply of food for the human race is inherently elastic and that this lack of elasticity is the main factor governing the rate of population growth, she advocated that population growth is an independent variable which in its turn is a major factor determining agricultural developments (Boserup 1965). The growth rate of food production will accelerate when population grows since it forces the population to intensify land-use and increased use of inputs. This holds as long as fallow land is available and the population density threshold value has not been reached. In summary: agricultural developments are caused by population trends rather than the other way around. Her viewpoints were largely ignored by both Ehrlich and the Club of Rome whose studies fell in much more fertile public grounds. The reasons hereto may be related to the fact that there was ample food in Europe and the USA and that the postwar babyboom generation felt a need to change the world.

Facts and figures

Historical estimates of world population are published at the website of the US Government on population census (www.census.gov/ipc/www/worldhis.html). Estimates are based on various sources and the mean of the upper and lower boundary for the period -10000 BC to 2000 AD and the period 0 to 2000 AD is shown in Figure 0. Global population hardly changed up to 1000 BC and slightly decreased in medieval times. The real increase started from 1650 onwards when global population passed through the "J-bend" of the exponential growth curve. Population growth remained below 0.5% up to 1800 and was about 0.6% in the 19th century. In the first half of the 20th century growth was 1%, but the largest rate occurred in the second half of the 20th century when the world population grew over 2% in some years.

What has caused the exponential increase in human population since the 1600s? The main reason is science and technology – in particular medical, industrial and agricultural sciences. The conquest of infectious diseases in infancy and childhood and other medical inventions are the main contributors to the exponential growth of the human population. Another factor is the decline in traditional breastfeeding practices by urbanisation and by the premature introduction of animal milk or infant milk (Short 1998). Also the increase in food production in Europe in the 17th and 18th century

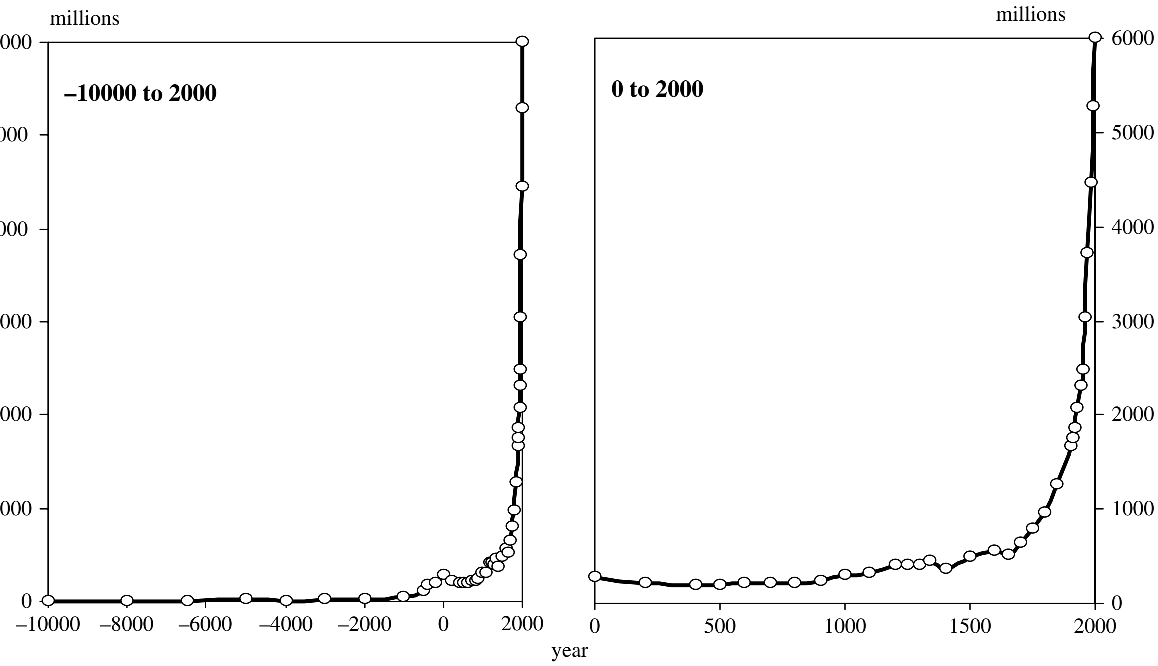

Figure 0. World population estimates for the years –10,000 BC to 2000 and the years 0 to 2000. Based on reconciliation of published data.

due to advanced cultural techniques (ploughing, liming) and more stable societies resulted in an increase in human population. Important inventions like the acidulation of bones by J.B. Lawes and technological marvels like the Haber-Bosch process that allowed the industrial production of urea indirectly caused a large increase in the European population. These were highly important and the invention and extensive use of superphosphate probably resulted in the economic domination of the world by Western Europe, according to Greenland (1994). Factors explaining the strong population growth in tropical regions were the abolishing of the slave trade, the suppression of tribal wars by European colonists, improvements in the health systems and the relieving of famine (Nye and Greenland 1960). Most of these factors became only significant in the 20th century.

Food production and soil science

Whether agricultural development is governed by population growth (Boserup 1965) or vice versa like Malthus and his followers proclaimed, the fact remains that more food needs to be produced when the population grows and if starvation is to be avoided. In the absence of massive food relocation, the extra food needs to come from either the available land through intensification, better crop husbandry practises and new high yielding varieties (yield increases) or through taking more land into production (area increases). Both production increase and area increase are dependent on a thorough knowledge of the soil and technological applications of this knowledge. Soil science, being essentially an interdisciplinary and applied science, has a long tradition of considering increased food production for the growth of the human population. This emerged in the 1920s (e.g. Penck 1928) and continues to date (e.g. Bouma et al. 1998; Greenland et al. 1997) and the next section reviews some early and recent studies in which soil science, population growth and food production are linked.

At the first Congress of the International Society of Soil Science (ISSS) in 1927, it was suggested that the world could feed at a maximum 15.9 billion people although at that time 7.7 billion was considered a more likely figure (Penck 1928). The estimate was largely based on the climatic maps of the world by Köppen as soil maps of the world were not available. The human population in 1927 was 1.8 billion of which 72% lived in the temperate zone. Penck (1928) quite correctly foresaw a dramatic increase in the human population and that most of the increase would occur in the tropics, which was first expressed in the early 1900s. The growing human population and the adequacy of food production were a point of concern in both the British Empire and in the Dutch East Indies although commercial developments had usually higher priorities than smallholder agriculture in the tropical colonies.

British studies

Prior to the Second World War, British administrators felt responsible for the feeding of the increasing population that had followed the cessation of war in many of their colonies and territories. Sir A.D. Hall, the first director at Rothamsted Experimental Station after J.B. Lawes, summarised the situation in the mid 1930s as follows "..native agriculture especially in those vast regions of Africa for which we are responsible, is inadequate to provide for the growing population, that is leading to land hunger and political unrest, that is wasting and will eventually destroy even the present limited production from the land". He stated that the increase of population in Africa has become very marked since the advent of European government, and in many tribes land hunger has developed already to an alarming degree. Unless remedial measures are taken, a state of general congestion is threatened within 30 years and famine is never far away (Hall 1936). He strongly believed that an increase in the amount of available food and the raising of living standards would be accompanied by an automatic reduction in the rate of increase of the population. That point has not been reached yet in Africa.

Hall's successor Sir E.J. Russell, who was Rothamsted's director for 31 years, showed great interest in the relation between human population growth and soil science and published a thorough book on the subject (Russell 1954). In the book's preface he mentioned that there have always been great inequalities in the food supplies of different countries. Prior to the Second World War such inequalities were accepted as part of the natural order of things which it was not for us (i.e. North-West Europeans) to interfere. He added that in the 1950s and 1960s many people in Europe and their descendants overseas had a growing feeling that they must do something to mitigate the hunger that oppresses so many in the undeveloped countries. That argument which was deeply-rooted is still with us today, particular in soil science.

Dutch East Indies

The link between population growth and soil science was recognised in the Dutch East Indies (Indonesia) and in particular on densely-populated Java. Based on earlier work, E.C.J. Mohr showed that Indonesia had a mean population density of 32 people km^{-2} in 1930 but with large regional differences: Java carried 316 people km^{-2} whereas population density in some parts of Sumatra and Borneo (Kalimantan) was only 11 people km^{-2}. The soil made all the difference: Java is largely volcanic and most fertile soils are derived from volcanic ejecta which also affects the quality of the irrigation water which is highly important in the rice based farming systems of Java (van Baren 1960). Mohr (1947) compared population densities for different districts near the active Merapi Volcano in Central Java (Indonesia) on volcanic soils and non-volcanic soils derived from limestone. Much higher population densities were found in the area were regular ash deposits are made by the volcano (Figure 1).

Further studies relating soil properties to population density showed that they were closely linked and the problem of the pressure on the land from an ever increasing growth of the population should take this into account (van Baren 1960). Transmigration of people from Java to sparsely populated regions of Sumatra, Papua or Kalimantan was a way in which both the Dutch colonizers and successively the Indonesian government dealt with the growing population on Java's fertile soils.

White (1941) considered soil fertility as a matter of national concern in relation to the rapidly growing population on Java. It is interesting that he considered two types of soil fertility loss: "emigration" of soil fertility through export crops, and "transmigration" through transport of produce within the archipel. He was amongst the first to consider the soil fertility conditions of the local farmers since most research in the Dutch East Indies was focused on large-scale plantations. The situation was no exception as soil science in the tropics prior to the Second World War largely focussed on plantation agriculture (Hall 1936). Knowledge on the soil resources of the Dutch East Indies increased rapidly in the 20th century. C.H. Edelman compiled a bibliography of soil science publications in the Dutch East Indies and from this it was calculated that there was on average 5.0 publications per year between 1850 and 1900, 44.4 publications per year between 1900 and 1925 and it had increased to 63.3 publications per year between 1925 and 1940.

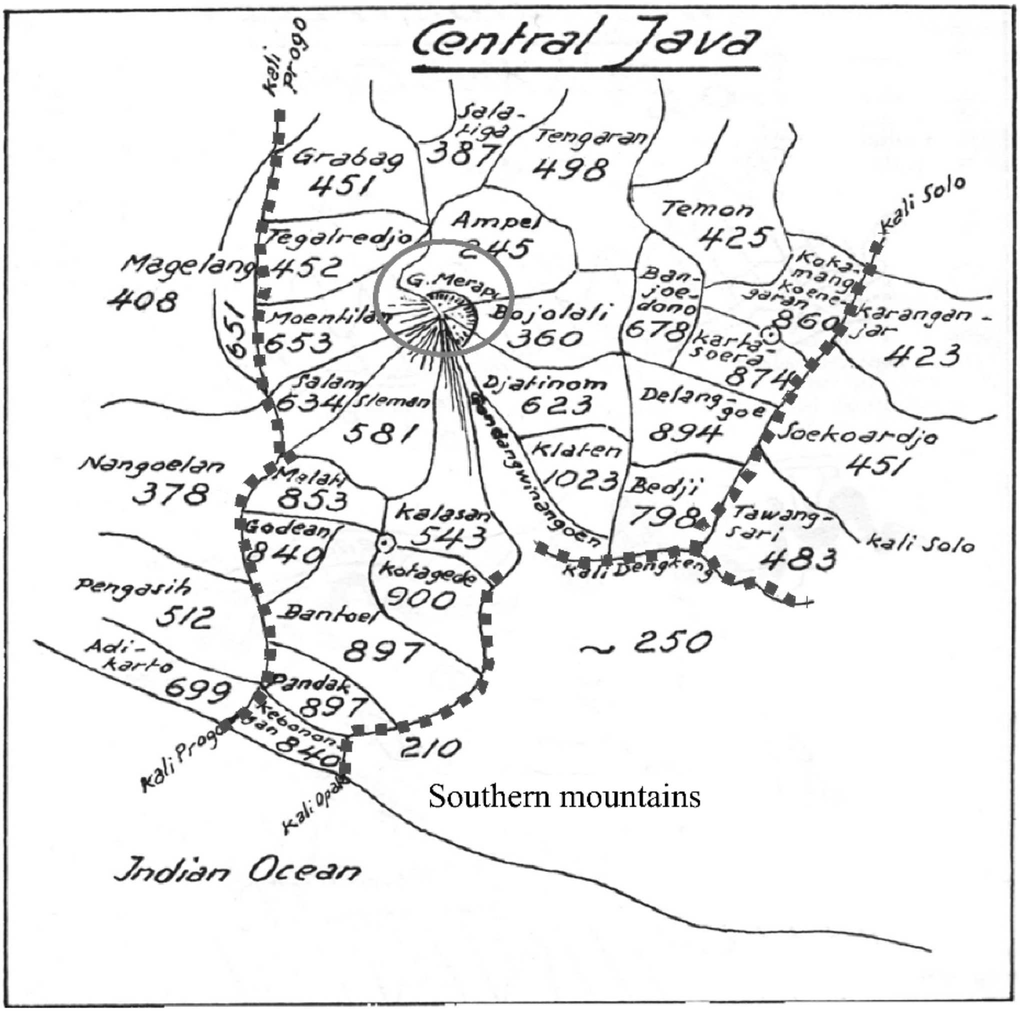

Figure 1. Population density (persons km^{-2}) around the Merapi Volcano (Central Java) in the 1930s. The Merapi Volcano (encircled) is an active volcano that regularly ejects lava and ashes that are deposited between the Pogo River in the East and the Opa and Solo in West (dotted lines). Soils in the Southern Mountains are generally poor. Modified after Mohr (1947).

Soil erosion and environmentalism

Soil erosion emerged in the first half of the 20th century as an obvious factor affecting food production in relation to the expanding human population. In the USA there was the question whether sufficient food could be produced for the growing population followed the "dustbowls" in the 1930s caused by severe erosion by wind. The New York Times stated in 1937 that if soil erosion was allowed to continue hunger would be common in the USA. This coincided with a serious economic depression in the USA, and an active fight of President F.D. Roosevelt against both depression and soil erosion. It resulted in the establishment of the Soil Conservation Service and the believe that productive soils can be maintained through centuries of farming if serious erosion is prevented (Bennett 1939).

A global overview of soil erosion was prepared by Jacks and Whyte (1939) titled "The rape of the earth – A world survey of soil erosion" (the American expurgated title was "Vanishing Lands"). They arrived at similar conclusions: the world food production was seriously affected if erosion would remain unchecked.

Depressing views on the future of the earth were also expressed in "An agricultural testament" (Howard 1940), "Our Developing World" (Stamp 1960) and "Our Plundered Planet" (Osborn 1948), containing quotes like ".. It is easy to understand in present times, with the world so crowded and in need of food, how any overpopulated country might deplete its land in a desperate effort to feed its crowding millions." The cover of "Our Plundered Planet" from 1948 stated "…we are more likely to destroy ourselves in our persistent and world-wide conflict with nature than in any war of weapons yet devised." The threats of the cold war and atomic weapons had yet to arrive in 1948. It is certainly not the case that soil science embraced the conclusions of all these books and the well-known Dutch soil scientist C.H. Edelman rightly called them "scare books" (Edelman 1951). He was also convinced that man is inventive so that a much larger human population would be possible provided modern agricultural techniques were available in developing countries.

Although environmentalism is generally associated with the 1960s and 1970s, these "scare books" make clear that the seeds for a pessimistic environmental outlook were sown in the first half of the 20th century (e.g. Hall 1936; Howard 1940; Jacks and Whyte 1939; Osborn 1948). As explained earlier, it was not until the 1960s that similar views gained widespread attention and acceptance. After the Second World War when international organisations such as the FAO were established and many countries were aiming at independence, the feeding of the growing population became an important area of research. Increasing food production was a concern in Western Europe because of the devastation after the war and the babyboom. Fortunately, science came out of the war with high status and was overall respected (Tinker 1985). There was great optimism and positivism in the 1950s and agricultural research rapidly expanded. Most, if not all, agricultural research was directed towards agricultural production, which increased dramatically, thanks to technological developments and major investments in agricultural infrastructure. Even though the term "green revolution" is mostly being reserved for agricultural production in developing countries, it could apply as well to post-war agriculture in Western Europe (Bouma and Hartemink 2002). There is no doubt that soil science played an important role in the increase of agricultural productivity, and Malthus would have been correct in predicting that population growth would outstrip food supplies but for the discoveries of soil scientists (Greenland 1991).

Soil science achievements

Various books and journal articles have reviewed the history and developments in soil science (Greenwood 1993; Hartemink 2002b; Russell and Williams 1977; van Baren et al. 2000; Yaalon and Berkowicz 1997). In addition, detailed reviews on developments in soil chemistry (Sparks 2001), soil physics (Raats 2001), soil microbiology (Insam 2001), soil variation (Heuvelink and Webster 2001) were recently published. These reviews all show the enormous progress that has been made in our understanding of the fundamentals of soil properties and processes. At the same time the reviews show in which areas (e.g. agriculture or the environment) soil science has made major contributions.

Lal (2001) summarised the cause of increased food demand in the 19th and 20th century and a number of causes were related to the soil and its management: ploughing, terracing, soil erosion control, irrigation and soil fertility management through manure and inorganic fertilisers. Mermut and Eswaran (2001) reviewed the developments in soil survey and mapping, soil technology, soil microscopy, pedology and classification of soils, and the mineral and organic components of soils. Several technologies have emerged from these developments including agroforestry, conservation tillage and precision agriculture. Major progress has been made in environmental soil science, and soil science has also been instrumental in studies on land degradation and sustainable use of natural resources and in studies on carbon cycling and sequestration (Mermut and Eswaran 2001).

Recent soil science and food production studies

At the international level, soil science and food production became closely linked in the 1960s and the motto for the 7th International Congress of Soil Science in 1960 in Madison was "Alleviate Hunger, Promote Peace through Soil Science". In his presidential address R. Bradfield mentioned that he can think of no single group of scientists who have more to contribute to feed the world than this group (Bradfield 1960). He also mentioned, quite correctly, that agriculturists including soil scientists have had more experience and in general more success in increasing food production than population experts have had in population control.

Nearly all studies from the 1930s to the mid-1970s focussed on soil physical and chemical properties limiting agricultural production (e.g. Bradfield 1960; Mohr

1947; Pendleton 1954). These studies were largely qualitative. The first quantitative study estimating the world food production was conducted in the mid-1970s. Following the publication of the report of the Club of Rome (Meadows et al. 1972), the Dutch Nobel laureate J. Tinbergen requested a group of Wageningen researchers headed by the soil scientist P. Buringh to estimate the maximum food production of the world if all suitable agricultural land would be cropped (Buringh et al. 1975). Hereto an assessment was made of land resources and productivity of more than 200 regions of the world introducing the regional aspects of food production and productivity. The absolute maximum production was expressed in grain equivalents of a standard cereal crop and estimated to be 40 times the production in 1975 when there were 4.1 billion people. It was assumed that less than half of the potential agricultural land of the world was cultivated (Buringh et al. 1975). Although the authors admitted that the results have only a theoretical and scientific value, the study showed locations where most productive land is available and that highest possible land productivity is in the tropics where double or triple cropping can be practised.

Characteristic for these early quantitative studies on global food production is the lack of scenarios or uncertainty in the calculations. Analogue to demographic studies which now largely focus on uncertainty *per se* (Lutz et al. 1997), such studies started to appear in the 1990s (Gallopin and Raskin 1998). A study by Kendall and Pimentel (1994) included three scenarios: continuation of present trends whereby population is to reach ten billion in 2050, a pessimistic scenario with 13 billion by 2050 and climatic changes, and an optimistic scenario assuming a population of 7.8 billion by 2050 and improved agricultural practises. In the first scenario food production cannot keep pace with population growth. The pessimist scenario assumed considerable climatic change causing 15% yield loss and gave little hope of providing adequate food for the majority of humanity by 2050. Only the optimist scenario considered that grain production might be adequate for the growing population by 2050 but it would require a doubling of the production and the implementation of soil and water conservation programmes (Kendall and Pimentel 1994). Similar views were expressed by IFPRI (Pinstrup-Andersen 1998).

Another recent estimate showed that a two- to four-fold increase in food production can be easily achieved to satisfy the growing population (Penning de Vries et al. 1997). The estimate was based on the potential production limited by radiation and temperature, by moisture in rainfed areas and it was further assumed that all surface water is available for irrigation. The authors conclude that actual (or attainable) level of agricultural production will be much lower for land is limited, water use is inefficient and there is loss of productivity because of soil degradation.

Soil degradation was taken into account in a study by Bouma et al. (1998). They explored the effects of different types of soil degradation (compaction, erosion, acidification) on agricultural production. Although the calculated values should not be considered as absolute the study showed that the effects of different forms of degradation cannot simply be extrapolated. So far no study has been conducted which quantified the effects of land degradation on global agricultural production. This is because no accurate data exist on the extent and types of land degradation (Hartemink 2003).

Soil science productivity

One way of measuring the productivity in a branch of science is to count the total number of publications over time for it can be assumed that the number is somewhat proportional to developments and advancements. Figure 2 presents the cumulative increase in soil and agricultural journals and the total number of soil abstracts published annually by CAB International since 1938 (Hartemink 2002a). The first soil science journal appeared at the close of the 19th century and a large number of soil science journals saw the light in the 20th century. Prior to the Second World War, there were only few scientific journals in which soil investigations were published. A considerable number of journals was established directly after the war and another peak occurred in the early 1980s. Only two journals were established in the 1990s and both focus on soil biology (Hartemink 2002a).

The trend in soil science abstracts is somewhat similar to the cumulative number of journals. The main cause for the increase is the growing number of soil scientists which is presently estimated to be 50,000. No accurate data exists on the number of soil scientist over time, but total members of the International Society of Soil Science (now IUSS – International Union of Soil Sciences) is depicted in Figure 2– data from (van Baren et al. 2000). It closely follows the number of CABI abstracts and the cumulative number of journals. It has

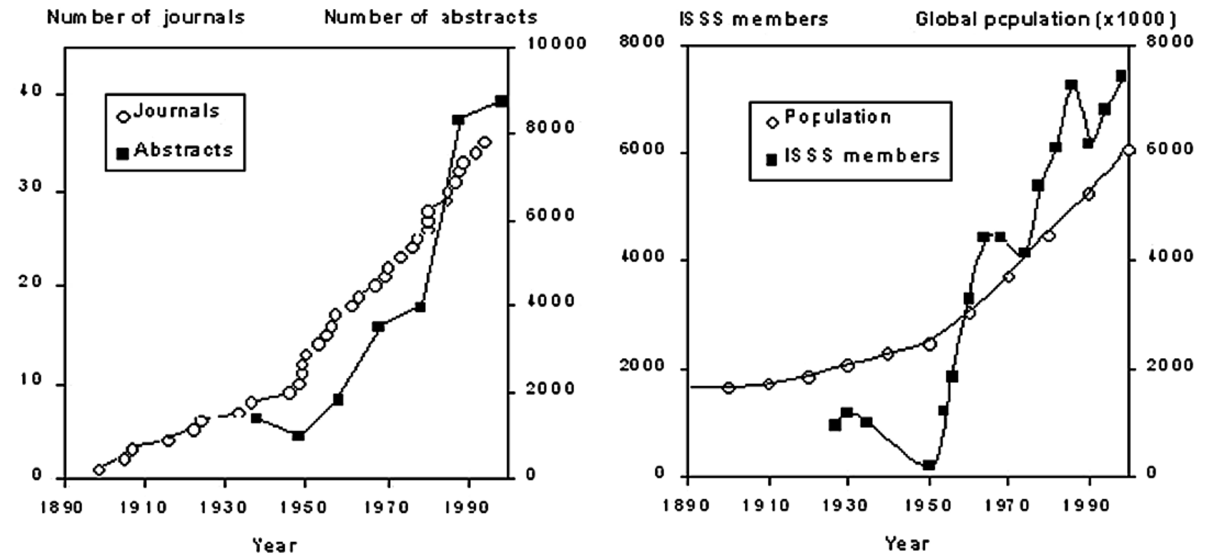

Figure 2. Cumulative number of soil and agricultural journals and number of soil science abstracts in CAB International "Soils and Fertilizers" (graph A), and number of ISSS members and changes in global population (graph B). CABI abstract data from Hartemink (1999), ISSS member data from van Baren et al. (2000) and population data based on reconciliation of published data by the United Nations.

been estimated that the annual increase in soil publications is about 5%. The right-hand side of Figure 2 depicts the increase in world population since the late 1800s and shows that number of journals, abstracts and ISSS members increased more steeply than the global population in the second half of the 20^{th} century. It thus appears that soil science is successful and very productive according to these measures. A recent analysis of papers in the global soil science journal Geoderma, revealed that there have been important shifts in soil science since the late 1960s, and much more desk studies are conducted at the expense of laboratory and field studies (Hartemink 2002a).

Population growth estimates

Projections

Since 1950, the world population has grown almost linearly (Figure 3). A linear regression through the 1950 to 2000 data showed that the average increase was 73 million people per year. The regression was highly significant and a high correlation was obtained ($r^2 = 0.994$). Official statistics have shown that the annual increase in human population was 85 million in the late 1980s and had decreased to 80 million per year in 1995 (Smil 1999). Currently the world population is growing by 1.3% per year, which is significant less than the 2.0% growth rate of the late 1960s. Population growth has been different in different regions. More than 80% of the population lives in developing regions, and Asia accounts for 61% of the world total. Two out of five people in the world live either in China or India. According to the population division of the United Nations, Africa's population is now larger than that of Europe but in 1960 Africa had less than half of Europe's population.

Projections for the period 2000 to 2050 are also given in Figure 3. It has been estimated that the world population would be 9.4 billion by 2050. Fischer and Heilig (1997) of the International Institute for Applied Systems Analysis, estimated that the average population increase between now and 2015 is 80 million per year which will decrease to around 50 million per year in 2050. Doubling of the human population by 2050 is therefore unlikely and the UN Department of Social and Economic Affairs has also lowered its forecast to 8.9 billion in 2050 as global population growth is slowing down (Lutz et al. 1997; Smil 1999). About one-third of this drop is due to the unexpectedly dire ravages of AIDS in sub-Saharan Africa and parts of the Indian subcontinent.

Population growth is also slowing down due to a change of attitude in the developing world, which

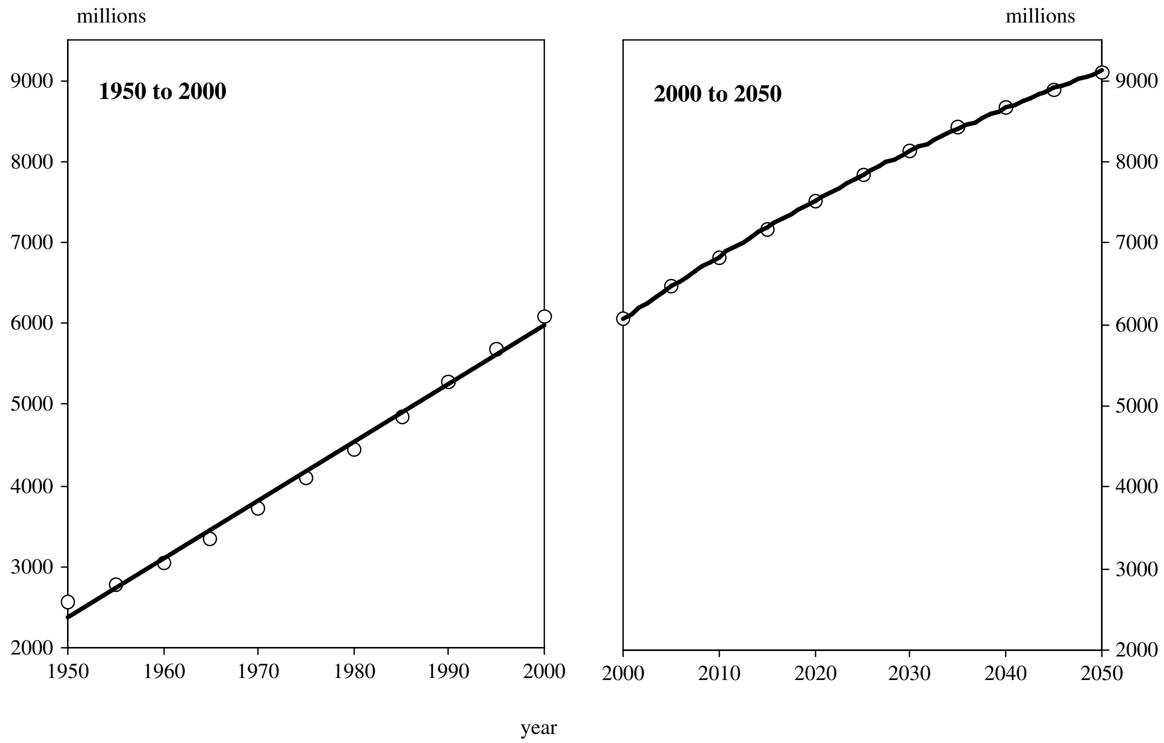

Figure 3. World population estimates for the years 1950 to 2000 and projections for the years 2000 to 2050. Based on reconciliation of published data.

accounts for over 95% of the population growth. In 1969, people in the developing world had an average of six children compared to three today. The population keeps on growing, however, because more babies survive and old people live longer and in Africa each women has on average five children. By 2050, there will be three times as many people in Africa than in Europe – if AIDS allows it. Of the 34 most AIDS affected countries, 29 are in Africa and life expectancy has been reduced on average by seven years (Anon. 1999). Deaths due to AIDS during 2000 in sub-Saharan Africa was estimated to be about 2.4 million and almost 9% of the adults was infected with HIV/AIDS as opposed to 0.6% in South and South-East Asia (0.47 million deaths in 2000) and 0.2% in Western Europe (7000 deaths in 2000).

Uncertainty

Population forecasts have a mixed record and they are no worse than forecasts by economists, meteorologists and others who have to deal with complex and partially understood systems. However, demographic projections could point the way for ecological and environmental forecasts which are also bedevilled by uncertainty (Tuljapurkar 1997). Much of the demographic work now focuses on the forecasting of uncertainty, *per se*. A recent report uses a new probabilistic approach that makes use of expert opinion on trends in fertility, mortality and migration and on the 90% uncertainty range of those trends in different parts of the world. It was concluded that the chances for a doubling of the world population by 2050 are less than a third (Lutz et al. 1997). This is based on the expert opinion that human fertility will continue to fall everywhere trailing the decline of mortality by about a half-century (Tuljapurkar 1997).

A new focus of attention is developing in demographic studies and in Western Europe and the USA the focus of the public, political and scientific concern shifts from global population growth to population ageing (Lutz et al. 1997), or as Tuljapurkar (1997) puts it "..for individuals, families and countries everywhere, the largest question of the next few decades will almost surely be, how to age gracefully". Two hundred years after Malthus' essay that is quite a shift of focus – at least for those parts of the world where food is ample.

The fear exists that the issue of ageing will detract the much-needed attention from those areas in the world where population keeps on increasing, hunger is widespread and a higher food production is needed to nourish current and future generations. That combination is mostly found in developing countries in tropical regions

Future outlook for food production

The world produces more than enough food at present to feed everyone, but nevertheless many people still starve or are undernourished (Latham 2000). In absolute terms the world already produces enough food to feed ten billion people but the problem is that most of it is fed to animals. It is poverty and not a physical shortage of food that is the primary cause of hunger in the world (Buringh 1982; Latham 2000; Pinstrup-Andersen 1998). Additional problems are inequitable distribution of food supplies, spoilage and other losses between production and consumption, politics (Ross 1999) and war and trading policies. Many international aid programmes aim to alleviate poverty for it is the main cause for hunger and environmental degradation (McCalla 1999). So total global food production is not a good indicator, or as Dudal stated: It is not enough for the world as a whole to have the capability of feeding itself, it is necessary to produce more food where it is needed (Dudal 1982).

Between 1960 and 2000 the world population doubled. But the green revolution during that period brought about substantial increase in food production and quality, these increases resulted from better varieties, improved irrigation and drainage, increased fertiliser use, improved pest and weed control, advances in food storage and transport, increased area under agriculture (Ross 1999). The impact of land degradation on food productivity is largely unknown. In addition there is the loss of land to non-agricultural use which is high (Buringh 1982). There is also limited extra land to take into production (Eswaran et al. 1999; Young 1999) in contrary to predictions made in earlier studies (e.g. Buringh et al. 1975; Meadows et al. 1972).

Prospects for increasing food production depend on improved technologies, a biotechnological revolution, widening of food sources (e.g. sea weed), and more land in production (Ross 1999). Doubling yields in complex and intensive farming systems without damaging the environment is a significant challenge (McCalla 1999). Progress towards a 'greener agriculture' will come from continued improvements in modern high-yield crop production methods combined with sophisticated use of both inorganic and organic nutrient sources, water, crop germplasm, pest management and beneficial organisms (Sinclair and Cassman 1999).

An important consideration when discussing food production and population growth is undernourishment, which is referred to by FAO as the status of persons whose food intake does not provide enough calories to meet their basic energy requirements (FAO 2000). In 1999, FAO estimated the incidence of undernourishment in the developing countries at some 800 million persons or 18% of the population. It was 960 million in the late 1960s, or 37% of the population (FAO 2000). Projections indicate that it will decrease to 576 million by 2015, and to 401 million by 2030. So both absolutely and relatively the number of undernourished people is on the decline and projections for the future show improvement although hundreds of millions people remain undernourished in the future. Much depends on political resolutions and will-power but if all resources are harnessed, and adequate measures taken to minimise soil degradation, sufficient food to feed the population in 2020 can be produced, and probably sufficient for a few billion more (Greenland et al. 1997).

Discussion and conclusions

Human population grew very fast in the past century and much of this growth occurred in tropical regions. There is no doubt that the concentration of people had environmental implications and in many cases it is likely that the environment has degraded. There are also cases whereby the environment is improved (Tiffen et al. 1994). Various studies in the past predicted gloom: more people, less to eat, scarcity, starvation, misery, war, environmental devastation etc. Obviously, these studies need to be examined against the available information in their times, but it could be argued that the political and emotional content often exceeds the scientific content including the uncertainties in the predictions. But did they help? It is impossible to appraise whether Ehrlich's efforts in predicting gloom have been helping Earth, but we do know now that most of his predictions were wrong. Recent studies have advocated that the widespread environmental problems are grossly exaggerated (Huber 1999; Lomborg 2001).

On the extreme, there are two groups in the world, which either believe that food production and yield increases have reached a plateau (the pessimists) or those who argue that sufficient food can be produced for many billions to come (the optimists). The pessimists, and followers of Malthus, believe that the world is approaching its carrying capacity, that no more cultivable land is available and land degradation is widespread, and that production cannot be sufficiently increased to decrease the 800 million or so who are chronically malnourished (Pinstrup-Andersen 1998). They also believe that socio-economic constraints limit the adoption and spreading of improved cultural practises. The optimists believe that there is room to grow more food by taking new land under cultivation, that the green revolution has not run out of steam and that biotechnology has great potential to feed the growing population. The optimists believe that future generations would produce enough geniuses to solve the problems that more people would cause. Both pessimists and optimists have non-scientific motives in their baggage, and apart from political or emotional motives, they largely base their conclusions on the projections of agricultural production. The wide divergence in these projections can be traced to the different methodological perspectives of ecological and neo-classical economics (Harris and Kennedy 1999).

It can be argued that the preaching of gloom is fruitless unless it is underpinned with science, and is harmful as it encourages fatalism instead of much needed determinism. Given the many unknowns it is fortunate that the discussion on the carrying capacity of the world continues. Like any important subject, the discussion should be based on the collection and careful interpretation of facts and figures in which research plays a major role. Science can provide much needed answers and guide the future focus of the political and research agenda (Greenland et al. 1997). Since agricultural production is largely depending on the soil's productive capacity, soil science should be in the forefront providing the much-needed data on soil resources and scenario studies how soil and land-use changes affect food production. However, it seems that interests of the developed world moves to human ageing instead of population growth. This, in combination with reduced funding for soil research (Mermut and Eswaran 1997), and the inability of the soil science community to clearly demonstrate the importance of soil science (Bouma 2001), is a serious matter of concern.

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