SUSTAINING NATIONAL WATER SUPPLIES BY UNDERSTANDING THE DYNAMIC CAPACITY THAT HUMUS HAS TO INCREASE SOIL WATER-STORAGE CAPACITY

by

Glenn David Morris

This dissertation is completed in a holistic style which reflects the wider knowledge base necessary for study into sustainable agriculture, and is submitted in partial fulfillment of the requirement for the degree of Master of Sustainable Agriculture.

Faculty of Rural Management
The University of Sydney
July 2004

ABSTRACT

Despite volumes of technical advice from mainstream scientific disciplines and continued alteration of natural environments, conventional systems of land management have been unable to maintain or improve the sustainability of natural land and water resources. Hydrological system breakdown as a result of land degradation is now threatening to severely impact upon agricultural as well as city water supplies.

This study has identified a possible solution to the problem of increasing water shortages by investigating the natural ecological processes which are responsible for creating robust water systems in nature, and suggesting that it is now time to redesign the management systems of an industrialized era which have failed to maintain soil and water resources.

A thorough review of literature to quantify the water-holding ability of humus indicates a biological solution is possible to the growing water crisis in Australia. The initial discussion describes the negative cycle of depletion created by falling humus levels, reduced water-holding ability and continuing land degradation in Australia. The main body of work discusses the complex nature of soil humus and the processes necessary to build soil humus levels, as well as an investigation as to a reliable guide for estimating the water-holding capacity of soils containing varying levels of soil humus at a catchment level. Finally a number of farming systems are discussed which provide alternatives for increasing soil humus as well as ensuring that new systems of land management are genuinely designed to be truly sustainable.

The multi-faceted benefits of soil humus ensure that any well designed program to increase soil humus for improved hydrological functioning would be equally beneficial in areas such as farm productivity and the abatement of greenhouse gases.

A major finding of this study was that, the subject of soil humus is critically under studied and thoroughly underestimated as a component of land and water management systems. It was found that the water-holding ability and nutrient status of soils can be dramatically improved by the development of land management systems which enhance the creative processes of soil biology and the naturalised agro-ecosystem.

Co-incidentally, the improvement in soil humus levels leads to soil structural improvement and increased plant density and ground cover, greatly alleviating the damaging factors which cause land degradation and water system breakdown.

The quantitative results of this extensive review were to find that one part of soil humus was able to store approximately four parts of water, demonstrating significant potential gains in soil water storage capacity at a catchment level.

Finally it was concluded that national water supplies can not only be sustained, but more importantly enhanced through the adoption of a better understanding of land management practices which enhance a dynamic state of soil humus development in Australian soils.

Dedication

Dedicated to my father in heaven, his grandchildren on earth and all the future generations that walk on this magnificent planet.

Table of Contents

Chapter 1 Introduction - Ecosystem Regeneration

Fresh water, fertile soils and clean air are the natural foundations of life and form the basis of a safe, peaceful and prosperous society. It is the responsibility of every society that these basic elements are passed on to future generations in abundance, just as they were passed onto past and present generations. This study recognizes that the present management of these vital resources has lead to a state of deterioration and that they will continue to decline further unless urgent steps are taken to address the foundation causes of their demise.

Recent periods of extreme drought and the associated depletion of water supplies in Australia have highlighted a critical dependence on natural systems and brought about much discussion on water management. Of primary concern has been the debate over the allocation and use of reduced water supplies. This report aims to change the focus of acceptance of natural resource decline to one of opportunity. An opportunity to commence an unprecedented era of natural soil improvement, and water system enhancement.

Using a holistic, inter-disciplinary and simplified approach this study investigates a potential solution to some of Australia's most threatening resource challenges. A natural solution, which combines two of the earth's major global material cycles, the carbon cycle and the hydrological cycle.

This study attempts to quantify the potential capacity of soils to store additional water for given increases in soil organic carbon and humus, identifying that the importance of this relationship is vital to understanding the essential role that humus performs in maintaining a functioning hydrological cycle. Society needs to accept that the health of the land and water resources we depend on is created by complex interactions between living organisms, inorganic minerals and the waste materials of plants, animals and microorganisms.

Suzuki and Dressel (2002, p.68) state that under a growing revolution in sustainability, "mainstream science and economics do not reflect the latest findings of physics: that relationships between components are the key to understanding their functions, and that the whole is a great deal more than the sum of its parts". This statement helps explain the need for a new way of thinking, if rivers are to be restored or if salinity is to be slowed, how can water losses be reduced from the landscape. An understanding of soil processes is a vital necessity in developing sustainable systems for land and water resource management.

This study aims to demonstrate the importance of building soil humus levels in order to maintain a robust hydrological system. After reviewing the pertinent literature on the relationship between humus and water–holding capacity a model will be developed to serve as a guide in calculating the additional water holding capacity of soils at a catchment, state or national level.

Methods for regenerating stable humus levels in catchment soils will be discussed, including a range of sustainable farming systems which have been developed to encourage the accumulative soil building processes of natural biological systems.

Chapter 2 Background on Environmental Issues

Land and water resources in Australia can be improved to a healthy status when the foundation cause of land and water degradation is acknowledged. In order to restore water supplies an understanding of why water losses have occurred is necessary. By identifying the cycle of declining humus, reduced water holding capacity and increasing land and water degradation, programs can be developed to reverse the cycle. While it is well understood that many forms of land degradation have had a devastating effect on the Australian landscape it is less commonly realised that the foundation cause of many of these problems is common to them all. The **loss of water holding ability** in Australian soils has initiated a devastating cycle of terrestrial and marine degradation ranging from the visible effects of soil erosion to the slower and more insidious effects of dryland salinity, acidity and marine sedimentation.

The Australian Agricultural Assessment (2001) estimates that about 127 million tonnes of sediment enters Australian rivers from hillslopes, gullies, and riverbanks each year with about 70,000 tonnes of phosphorous attached to the sediment. Yencken and Wilkinson (2001, p.266) state, "the unsustainability of current agricultural systems relates to the fact that, unlike natural systems, they are unable to use all of the water that falls over a year and so they leak much more water, nutrients and salt than the natural systems they replaced". The inability of Australian soils to retain water has been created by a modern era of agricultural science and land management which has largely neglected the integral relationship between soil humus and water retention.

Jones (2001, p.2) comments that the experience given by European explorers was that, "soils were variously described as mulched, peaty, soft, loose, friable and high in humus, even in relatively low rainfall areas". Soils of this description would be in such a state that it would not only absorb large quantities of rainfall but would also retain this moisture for gradual release over time. A well structured porous condition of the soil would therefore act as a regulating system against the extremes of flooding and the rainless periods of drought. It would also act as a measuring system for providing basal flows to perennial watercourses over long timeframes. Mollison (1992) states, "free (interstitial) water can as take as long as 1–40 years to percolate through to streams, greatly alleviating droughts, it also recharges the retention storages along the way". Eventually the water would filter through the soil profile to replenish the extensive ground water systems which are currently being pumped faster than they are being recharged (Yencken and Wilkinson, 2000).

The continual loss of water–holding ability in Australian soils has been brought about by a constant decline in soil humus levels and an associated deterioration of soil structure. There are many factors which have contributed to the decline of humus levels in Australian soils. Primarily land clearing, constant grazing pressure and extensive soil tillage have all added to humus depletion. The removal of organic material through grazing, farming or fire, combined with the destruction of the microbial environment in the soil, has effectively stopped any significant level of humus production.

Chapter 3 Quantifying the Water Holding Capacity of Humus and Soils Containing Humus: Part A

The positive relationship which exists between soil organic matter and water-holding capacity is one which most scientists, horticulturalists and agriculturalists acknowledge as being important. Occasionally though there is reference made by those with an understanding of natural soil processes to the actual level of moisture retained by humus. Due to the implications of water–holding capacity to land degradation and also water supplies this relationship between water and humus is of national importance. Wheeler and Ward (1998, p.16), state, "humus is the primary reason why soil is able to hold water". They make reference to soil humus holding four times its weight in water. Podolinski (1985) stressing the colloidal properties of humus estimated that humus is capable of holding 75% of its volume in water, adding that the water will neither evaporate or leach out. Podolinsky (1985, p.21) cautioned about losing sight of the wholeness of this product, adding "that no matter what can be analyzed and measured and argued and hypothesized about, humus as a whole is a colloid". Before continuing to quantify the water-holding capacity of humus it is necessary to understand the formation and physical properties of the humus colloid. A better understanding of its impact on soil processes and water-holding capacity can then be gained.

Chapter 4 Formation of the Humus Colloid

4.1 Biological Processes

In order for organic matter to be transformed into humus the soil must be able to provide suitable conditions for microorganisms to exist. Soils which already contain good levels of humus will display good porosity, levels of oxygen and water and will enhance the production of new humus. Soils which have been subject to humus depletion, as a result of compaction, mineral depletion and the overuse of synthetic chemicals will restrict the number and performance of microorganisms and slow the rate of soil improvement. Stable humus formation in the soil begins with the interactive breakdown of plant and animal remains carried out by a diversity of soil fungi, algae, bacteria, actinomycetes earthworms, macro fauna, meso fauna and micro fauna.

4.2 The Organic-Inorganic Synergy

The ability of soils to build water-holding capacity is related to their potential to store and protect the organic carbon (humus) from complete microbial breakdown. This protection is aided by various chemical and physical bonds with the inorganic soil fraction.

Of particular importance in the context of soil water retention is the effect of the stable humus colloid on soil structure, stability and water storage capacity. Gedroiz (1929, cited in Waksman 1936, p.314) stated, "the organic colloids in the soil exert an aggregating effect on the inorganic colloidal particles of the soil, favoring the formation in the soil of micro-structural units, which possess a marked resistance against the disaggregating action of adsorbed monovalent cations; the removal of the colloidal humus part of the soil increases the dispersing action of these cations".

4.3 Chemical Bonds in Humus Formation

Tan (2003) attributes the formation of favorable soil structure to the interaction between humic acids and inorganic clays. Tan (2003, p.254) states, "the effect of humic acid is to create and preserve a stable structure that can provide the proper amount of pore spaces for the storage of optimum amounts of water and oxygen". The formation of the humic matter/clay colloid is achieved by a process of bridging, whereby the negatively charged humus colloid is bonded to the negatively charged clay colloid, either with a positively charged H atom in a water bridge, or via metal bridging with an Al or Ca cation (Tan 2003). The formation of this stable humic matter/clay colloid may then lead to the ideal soil conditions for biological performance, water storage capacity and environmental stability.

Although the humus content of the soil is often very low (below 3%) compared with the inorganic component of the soil matrix it is the ability of humus to act as a catalyst for improved soil structure and water-holding ability which is of vital importance. Ehrenberg (1924, cited in Waksman 1936, p.308) observed that "the humus sol first peptizes the aggregated clay particles; this is followed by the formation of a layer of absorbed humus sol around the clay fractions; as a result of this, the latter require much higher concentrations of electrolytes for flocculation, *since they behave as if they were made up entirely of humus*".

This influence over the entire soil matrix may be explained due to the ability of the spongy extracellular material (humus gel) to coat the inner surfaces of the inorganic soil pores. The development of a porous coating upon the micro and macropores creates an exponential increase in the number of sites for water absorption and storage. Waksman (1936,p.308) stated that , "in a soil with favorable texture, one finds good drainage and aeration, while too much leaching and evaporation are prevented.

Humus through its effects on the inorganic soil fraction could therefore reduce water percolation rates through the soil as well as preventing the surface runoff of water. This function would aid greatly in reducing salinity, erosion, sedimentation, etc. The soil would function as a huge water reservoir precisely as nature intended.

Alway and Neller (1919, cited in Waksman 1936), who carried out detailed studies on the relationship between soil humus and water-holding capacity found that, "an increase in the humus content of the soil is accompanied by an increase in the moisture holding capacity, probably due largely to the inhibition of water by the humus gel".

4.4 Physical Processes of Humus Formation

Kay (1997) describes the formation of stable humus in the soil as a physical process by which humus material and inorganic matter interact; protecting the organic carbon from further microbial attack and in the process, **sequestering organic carbon.** Through the process of humification humus material impregnates the internal surfaces of pores in the soil matrix as well as adsorbing to the exterior of mineral particles, to give a positive affect to both soil structure and water-holding capacity.

Humus through its unique ability to store nutrients and water should be considered to be the major component in maintaining hydrological regimes in the soil as well as in watercourses and in the atmosphere, through the soils effect on continued plant growth and evapotranspiration rates.

4.5 The Physical Makeup of Humus

The physical descriptions of soil humus are quite varied due to the fact that the composition of humus is very complex, existing in a state somewhere between a liquid and solid form. More precisely humus is described as an amorphous material, that is, a material lacking definite form and having no specific shape.

Electron microscope investigations of humus have identified a loose spongy structure ideally suited to holding water and air. (Khan 1971).

Chapter 5 Developing a hypothetical model to be used as a basis for quantifying the water-holding capacity of humus and soils containing humus

This study has aimed not to define the precise results of a scientific study, but rather to understand a complex interaction between the humus soil system and the associated hydrological processes within the soil. Waksman (1936, p.7) highlighted a need for understanding the natural processes of the soil system, "humus is not in a static, but rather in a dynamic, condition, since it is constantly formed from plant and animal residues and it is continually decomposed further by microorganisms". Given that the stability of land and water resources are dependant on the functions of soil humus and humus is constantly being utilized and transformed it would be logical to ensure that the provision of material and conditions for ongoing humus production is maintained. The present era of industrial agriculture and forestry has failed to stress this fundamental element of sustainable landscape management.

After a comprehensive review this study has established that the extracellular (humus gel) material in the soil, sometimes referred to as active humus is largely responsible for water retention. It also shows that microorganisms are constantly breaking down the humus which is essential for a resilient soil structure and fully functioning hydrological cycle, backing up the view held by Waksman (1936) that humus exists in a dynamic state, constantly being formed and continuously being broken down. Additionally this study has found that the fractions of stable humus responsible for the greatest degree of water retention are the first to be decomposed suggesting that if the hydrological functions of catchment soils are to be restored and maintained there is a need for greatly increased turnover of organic matter into active humus. This study also shows that the lignin derived fractions of stable humus play a critical role in complexing with clay and metal ions to increase the stabilized structure and porosity of the soil.

Australia's soils, rivers, water supplies and marine environments are therefore ultimately dependant on the development of land management systems which lead to an improvement in this dynamic state of soil humus.

5.1 The Humus/Water-Holding Capacity Ratio

By combining modern testing procedures with the results of extensive field research, a guideline has been established for the relationship between soil humus and water-holding capacity.

The combination of spectroscopic analysis, electron micrographs and water release characteristics used by Kay (1997), produced an organic carbon (humus) to water-holding capacity ratio of 1: 2.6 to 6.5, corresponding with the estimated humus : water ratio established by Waksman (1936) 1 part humus held 4 to 6 parts water, and
field trials by Always and Neller (1919) 1 part humus held 4 parts water and
Wheeler and Ward (1998) 1 part humus held 4 parts water (Based on USDA figures)

For the purpose of developing a broad scale and practical model for estimating increases in water-holding capacity for given increases in humus at a catchment level it is suggested that a 1% increase in soil humus will result in a 4% increase in stored soil water. Also for the purposes of a hypothetical model and practical implementation an average figure of 4,000,000kg will be used in calculations for a 30cm deep soil profile over 1 ha. Realistic target increases in soil organic carbon (humus) could be given for set areas of land use and soil characteristics or alternatively an average organic carbon increase could be set for catchments based on the variation of soil types and topography within a catchment. The use of figures is purely to demonstrate the potential improvement in water retention and the potential volumes of water saved from escaping catchment areas.

5.2 Water-Holding Capacity Increase for One Hectare for Varying Levels of Humus Increase

Using the guideline ratio, which has been established for additional water retention the following gains can be expected.

Humus Increase	Increased Volume of Water Retained /ha (30 cm) (OC% x 4,000,000kg x 4)	
0.5%	80,000 litres	(average 2004 level)
1 %	160,000 litres	
2 %	320,000 litres	
3 %	480,000 litres	
4 %	640,000 litres	
5 %	800,000 litres	(pre-settlement level)

The Clarence Valley catchment has an area of 2,300,000 ha², a 0.5% increase in humus (organic carbon) would therefore store an additional 184,000,000,000 litres of water following an adequate rainfall event.

Wheeler and Ward (1998) estimate a 25mm rainfall event over one hectare contains 250,000 litres of water. Their studies suggest that soils with only 1% humus would be able to store less than half of the water in a 25mm rainfall event.

In broad terms soils would therefore need to contain approximately 2½ % humus in the top 30cm in order to retain the volume of water delivered in just 25mm of rain. At the upper end of the scale, Mollison (1992) noted that soils of fine texture and high organic matter content were capable of storing 100 to 300mm of rain in the top 30cm of the soil profile. The volume of water contained in 300mm of rain would equate to 3,000,000 litres of water stored over one hectare.

A 100mm rainfall event over the entire Clarence Catchment would deliver 2,300,000 megalitres of water to Clarence Valley soils. With each additional increase of 1% humus over the valley, an additional 368,000 megalitres of rain would be stored in the soil water storage system, gradually recharging ground water systems and percolating through to water courses to provide perennial water flows, even in times of low rainfall. Average pre-settlement organic carbon levels have been estimated at being in excess of 5% compared with organic carbon levels now, which are found to be at less than 1%. Over an area the size of New South Wales (80,142,800 ha) that would equate to a drop in water-holding capacity of 51,291,392 megalitres following an adequate rainfall event (fractionally more than 50mm of rain).

In a river catchment basin such as the River Murray (1,057,000 square kilometers) a 2% increase in humus would equate to an increase in water-holding capacity of 33,824,000 megalitres of water. This water would be withheld from deep drainage and rapid surface runoff which cause, raised water tables and other forms of land and water degradation. The increase in transpiration from additional plant growth would then become the catalyst for localized hydrological effects which would be again held in the effective soil horizon of plant roots creating a positive cycle of increased plant growth, humus formation, transpiration and rainfall.

As mentioned previously, this paper does not strive to give an accurate account of water volumes, but has tried to use a meaningful model to demonstrate the important role which humus (organic carbon) has to play in restoring hydrological functions in catchment areas.

It is therefore in the soil's water-storage capacity that the greatest hope lays for reducing land and water degradation issues and ensuring sustainable cycling of agricultural and natural resources, including water. The primary objective of land management beyond 2004 must centre entirely on improving the constant formation, quantity and cycling of soil **HUMUS.**

Chapter 6 Farming Systems Designed for Increasing Soil Humus & Water-Holding Capacity & True Sustainability

Conventional land management practices in Australia have created soil conditions which restrict the process of humification and add to further depletion of existing soil organic carbon. New land management systems must be designed which aim to increase the degree of organic matter cycling in the soil. By increasing the rate of organic matter turnover and managing soils to create the optimum conditions for biological activity, microorganisms will proliferate and increase their production of humus. With continued corrective management a positive cycle of further increases in biological conditions, humus production and agro-ecosystem sustainability will occur. Zimmer (2000) notes that beneficial organisms in the soil require the following conditions and materials in order to function:

- well-aerated soil (good structure),
- a moderate amount of moisture, (not to wet or dry)
- moderate temperatures,
- a source of food (organic material), and
- freedom from harmful soil conditions (toxic substances, strong salts, wrong pH)

The focus on creating the ideal conditions for humus production has lead to the development of a number of natural farming and grazing systems. These land management systems have not only recognized a need for adopting new systems of land management, but have also recognised the need to be a part of a new paradigm in sustainability.

The improvement of the hydrological cycle, as has been discussed is dependant on the microbial humification of organic material in the soil. Short term land management systems which increase plant growth and save water through the use of synthetic herbicides and harmful fertilizers do not create the safe biological conditions necessary for a dynamic cycle of humus production, the medium to long term affects will continue to degrade soil and water resources and continue to cause a loss of water supplies.

Williams (1991) writes, "Agriculture must avoid the solving of one problem by the creation of another. The crucial role of agricultural chemicals in conservation tillage requires that the fate and long term consequences of these chemicals be fully researched and understood…..A sustainable system is not one that finally collapses in its own poisons or transfers them to the adjacent ecosystem". A sustainable soil for food and water production should not be one that is not safe for children to play in, or one that deprives future generations of the basic essentials of life. A movement in farming systems to improve the cycling, and building of humus must be matched by improved biological and technological methods to suppress weeds and pests without the use of toxic poisons.

This new era of natural soil improvement and water enhancement must be achieved as a part of a wider society commitment to genuine sustainability.

6.1 Sustainable Farming Systems

Examples of sustainable agricultural systems of land management which are being developed in Australia to address the need for building and increasing soil humus cycling include: organic farming and biological farming; biodynamics; permaculture and holistic management systems.

While these systems alter in their approaches, their fundamental aim of improving the health status of soil through biological cycles is acknowledged as the basis for a sustainable agro-ecological society.

The maintenance of soil mineral balance is an essential component of the sustainable cycle of humus production. By providing the elements and structural conditions for increased microorganism activity the soil increases in fertility, water-holding capacity and organic matter production.

Due to the interconnected processes which exist between a balanced soil, soil biology and plant growth and the production of soil humus and the functioning of regional hydrological effects, every effort should be made to limit any negative inputs.

The excessive use of nitrogen is one input which can impact soil water processes in a number of ways, firstly the excess nitrogen leads to a massive increase in microorganism numbers which rapidly consume valuable soil humus, particularly as described earlier the active humus fraction. Secondly the excess nitrogen is highly leachable and as it leaches can often associate with calcium creating an inbalance in soil nutrients. Thirdly excess magnesium created by the removal of calcium can combine with nitrogen to form a magnesium nitrate salt which reduces the effect of the nitrogen. An increased rate of nitrogen is then required to achieve the same rate of plant growth (Sait 1998). The cycle of humus depletion is repeated until the soil totally collapses and hydrological processes cease.

By balancing the soil with the correct levels of non-harmful minerals both microorganism and plant processes can be optimized leading to a positive increase in soil humus levels and progress of the dynamic state of humus cycling. Lovel (2004) states, “soil biology is the nutrient sink that holds, enhances and releases the nutrients of the soil to the growing crops……While chemical processes work with water and solubility, biological processes hold within cell membranes and organic structures much that would otherwise be lost to water. Tragically, soluble nutrients tend to concentrate again many miles or hundreds of miles away – and in many cases they overburden and poison rivers, lakes, watertables and oceans”.
The application of soluble nutrients not only allows for the pollution of water systems and loss of soil minerals but of equally significant importance, is the loss of the soils natural water-holding ability and the loss of billions of litres of water from terrestrial water systems.

Economic decisions concerning the correction of mineral balance of a soil complex are usually based on the value of the commodity being produced. Due to the significant influence that soil humus has in maintaining a sound ecosystem, and the substantial role it plays in maintaining fresh water supplies there is a need for wider community support programs to assist land managers to start building soil humus levels.

Chapter 7 Co- Incident Benefits of Organic Carbon Sequestration

7.1 Reducing Carbon Dioxide Levels in the Atmosphere

A major co-incident benefit of developing carbon sequestration methods in management systems is the removal of carbon dioxide gases from the atmosphere. At present the increasing rates of carbon dioxide being released into the atmosphere threaten to bring about widespread disasters through climate change.
Forecasts from the Hadley Centre of the Meteorological Office in the United Kingdom forecast that if action is not taken to combat climate change, by the 2080s:

- Global temperatures will rise by about 3ºC;
- Large parts of northern South America and central southern Africa could lose there tropical forests;
- Some 3 billion people could suffer increased water stress;
- Around 80 million people could be flooded each year due to rising sea levels.
- About 290 million extra people could be at risk from malaria;
- The risk of hunger in Africa will increase due to reduced cereal yields

(Yencken and Wilkinson, 2000)

Hydrological cycles are forecast to be increasingly affected by climate change, including changes to soil moisture, groundwater and run-off. Additionally the intensity and frequency of monsoonal systems and the El Niňo-Southern Oscillation is likely to be altered (Yencken and Wilkinson 2000).

Carbon sequestration initiatives to improve local hydrological systems may have the additional benefit of reducing the rate of climate change. By applying recommended management practices to sequester soil organic carbon the total potential for carbon sequestration in the United States has been estimated at 144 to 432 million tonnes per year. Follett and Kimble(2003) state, " With the implementation of suitable policy initiatives, this potential is realizable for up to 30 years or when the soil C sink capacity is filled. In comparison, emission by agricultural activities is estimated at 43million tonnes C/y, and the current rate of soil organic carbon sequestration is reported as 17 million tonnes per year." Annual carbon sequestration in the United States using recommended management practices, is estimated at, 280 -620 kg/ ha for cropland, 40 – 200 kg / ha for grazing land and 100 – 430 kg /ha for forested lands.

The British Royal Society has estimated potential carbon dioxide sequestration on the worlds 2.5 billion acres of agricultural soils at 6.1 to 10.1 billion U.S. tons per year for the next 50 years (Sayre 2004).

7.2 Cooling Land Temperatures, Reducing Fire Risk and Creating Local Rainfall

The higher water- holding ability and increased transpiration effects of natural farming systems will be of significant importance in reducing the impacts of an increasingly warming climate, due to climate change. The dark color of humus and its ability to absorb radiant heat results in soils remaining cooler in summer and warmer in winter. Soil humus effects rainfall by supporting a higher degree of vegetational diversity and retaining more water in the soil to be extracted and exchanged for carbon dioxide in the process of photosynthesisation. Hamblin, cited in Yencken and Wilkinson (2000, p. 241)

> *Vegetational diversity is at the heart of biodiversity. The association of groups of plant species in characteristic associations, provide habitats (shelter, food and breeding places) of most of the world's fauna and microbial life forms. This diversity is in response to localised differences in soil, landform and micro-climate, so that the value here is a reciprocal one – with vegetational diversity dependant on soil, water and topography.*

Hamblin has recognised the need to view all aspects of a functioning ecosystem in a holistic manor, with soils dependant on plants, rainfall and topography, and rainfall being dependant on soils, topography and plant life.

Mollison (1992) notes the important role that plant life performs in maintaining hydrological cycles. Trees and other plants through the processes of condensation, evaporation and transpiration can account for up to half or more of all moisture returned to the air, the moisture constantly returning to the earth as rain and constantly transpiring back through plants to the atmosphere in exchange for carbon dioxide. Management practices which fail to view the entire landscape as a complex integrated system will invariably lead to a breakdown of the vital support systems which life depends on. The focus of this report on increasing soil humus to increase soil water holding capacity can be viewed as only one very small part of a far greater cycle of the grand material cycles.

7.3 Humus and Human Health

Increasing rates of disease in the community are raising the level of research into the links between human health and soil health, particularly the links between soil minerals and health. Albrecht (1975, p.187) stated that, "we are about to realise that good health lies very near to good fertile soil". Thirty years later, there is a multitude of diseases which are increasing at an alarming rate, including obesity, epidemic levels of cardio-vascular disease, diabetes, cancer, arthritis and other autoimmune diseases. It is the breakdown of important physiological functions due to mineral deficiencies which is causing the greatest concern (Brunetti 2003). Brunetti (2003) notes, a deficiency of magnesium and zinc can account for over 300 physiological malfunctions. Physiological processes such as DNA replication, digestion, immune function, endocrine synthesis, neurological activity, energy storage and release, muscle contraction and many others rely on catalysts, usually in the form of enzymes. Brunetti (2003) states, "all enzymes, without exception, are built on the presence of micronutrients".

Albrecht (1975, p.52) through his deeper understanding of soil and plant processes documented the need to connect human health with soil health, he states, "we have not yet understood, nor appreciated, agriculture as a collection of complex, but well-integrated, biological processes. We have comprehended some fragments of this natural art which science has studied deductively, but we have not yet constructed the whole of a scientific agriculture inductively. We have not seen the soil as plant nutrition and thereby as animal and human nutrition, or the soil as the very foundation of all agriculture."

The implementation of sustainable management systems which recognise soil humus as the foundation of land management has the capability to restore not only environmental processes, but also the levels of human health in society.

Chapter 8 Conclusion - The Sustainable Revolution

During the first industrial revolution separatist technological and scientific decision making has been applied to land resources and water supplies without an understanding of the biological processes which govern the creation of natural hydrological and nutrient cycles. The policy of extracting water from rivers in large dams for agricultural and urban needs failed to ensure that the groundwater sources of river flows were managed sustainably. Replacing natural fertility with synthetic chemicals, although heralded as a green revolution due to increased yields, actually deteriorated the soil biological and physical conditions needed for sustainable water supplies and disease preventative food production.

The mining of soil humus without due recognition of its importance in soil structure and water-holding capacity has also lead to devastating land degradation and a serious alteration to atmospheric carbon levels.
A Global Environment Outlook report conducted by the United Nations Environment Program (1999, cited in Yencken and Wilkinson 2000, p.26), concluded that the decision making processes of the past century have resulted in a situation where:

> *The world water cycle seems unlikely to be able to cope with demands in coming decades, land degradation has negated many advances made by increased agricultural productivity, air pollution is at crisis point in many major cities and global warming now seems inevitable. Tropical forests and marine fisheries have been over-exploited while numerous plant and animal species and extensive stretches of coral reefs will be lost forever – thanks to inadequate policy response.*

The results of the first industrial revolution are conclusive. Water supplies, fertile soils and even the atmosphere have been so degraded that global material cycles are now in crisis.

Sustainability for future generations is now dependant on a new revolution, a revolution whereby the productivity goals of society are achieved by stimulating the integrated creative capacities of natural systems. Savory (2004) states, "over-grazing, overstocking and over-population were not the problem; rather, it was conventional decision making processes used by governments, organizations and individuals that simply did not provide a framework to manage natural systems".

The complexity of the natural systems requires a broader level of understanding than previous scientific disciplines have held. The sustaining of water supplies and soil production is no longer dependant on how much we can modify a system, but on how much we can enhance the natural creative processes within that system.
By using non-destructive management practices in well designed land management systems, the foundation of life, soil humus can be accumulated and used to store valuable falls of rain across catchments. Gradually the re-charged ground water system would release a continuous supply of water to river systems and the atmosphere, as

transpiration, to restore hydrological cycles and sustain the '**Water Supplies of a Nation'**.

Environmental stability, production efficiency, biodiversity enhancement and social justice are all achievable outcomes under a new revolution, where the enhancement of soil humus is the first priority of a sustainable society.

The Jewel of Humanity and the Soul of the Earth

~ Humus

References

The Alan Savory Center for Holistic Management, Holistic Management Model, online. Available at http://www.holisticmanagement.com/photos/HM%20Model%20Colr%20v12_3.gif.

Albrecht, W.A. 1975 *The Albrecht Papers Volume 1: Foundation Concepts*, 1st edn, Acres U.S.A., Kansas City, Missouri, U.S.A.

Albrecht, W.A. 1975, *The Albrecht Papers Volume II: Soil Fertility and Animal Health*, 1st edn, Acres U.S.A, Kansas City, Missouri, U.S.A.

Always, F.J. and Neller, J.R. 1919 A field study of the influence of organic matter upon the water-holding capacity of a silt-loam soil, *Journal Agricultural Research*, vol.16, pp.263-278.

Archinal, W. 2004, pers. comm., July

The Australian Agricultural Assessment 2001 Australian *Agriculture – setting the scene*, Commonwealth of Australia. Available http://audit.ea.gov.au/ANRA/agriculture/docs/national/Agriculture_Scene.html.

Bakken, L.R. and Olsen, R.A. 1987, 'The relationship between cell size and viability of soil bacteria', *Microbiological Ecology*, vol.13, p.103-114.

Bowman, R.A., Reeder, J.D. and Lober, R.W. 1990, *Soil Science*, Vol.150, pp. 851-857.

Chenu, C. 1993, 'Clay-or sand- polysaccharide associations as models for the interface between micro-organisms and soil: water related properties and microstructure, *Geoderma*, vol.56, p.143-156.

Ehrenberg, P. 1924, Die Bodenkolloide, 3rd edn, Dresden. U. Leipzig

Natural Resources Conservation Service 2003, Managing Soil Organic Matter: The Key to Air and Water Quality, online. Available http://soils.usda.gov/sqi/soil_quality/what_is/som.html

Forster, R.C. 1988, Microenvironments of Soil Microorganisms, *Biol. Fert. Soils*, vol.6, pp.189-203.

Gedroiz, K.K. 1929, The soil absorbing complex and the absorbed cations of the soil as a basis for a genetic soil classification, Nosov. Agr. Exp. Bull. 38.

Gedroiz, K.K. 1933, 'Influence of hydrogen peroxide upon the soil', in *Proceedings of 2d. Intern. Congr. Soil Sci*., Udobrienie i Urozsh, pp. 41-70.

Golchin, A., Oades, J.M., Skjemstad, J.O., Clarke, P. 1994, 'Soil Structure and Carbon Cycling', *Australian Journal of Soil Research*, vol 32, pp.1043-1068.

Hartikainen, H. 2003, *Humus – product and source of life*, Department of Applied Chemistry and Microbiology, Box 27, University of Helsinki, Finland, online. Available at http:/www.80-gateway1.ovid.com.opac.library.usyd.du.au/ovidweb.cgi.

Hayman P. 2003, pers. comm., Feb.

Jones, C.E. 2001, The Great Salinity Debate: Part III, Soil Organic Matter: past lessons for future learning. Available http://home.winsoft.net.au/stipa/salinity3a.html.

Jones, C. 2002, Northern Tablelands 'Rangelands Project' Technical Report, DLWC, Armidale, NSW.

Kay, B.D. 1997, 'Soil Structure and Organic Carbon: A Review', in *Soil Processes and the Carbon Cycle*, CRC Press, London.

Khan, S.U. 1971, *Soil Science*, vol.112, p.401.

Lal, R., Follett, R.F. and Kimble, J.M. 2003, 'Achieving soil carbon sequestration in the United States: a challenge to the policy makers', Soil Science, vol.168, no.12, pp. 827-845, online. Available http://80gateway1.ovid.com.opac.library.usyd.edu.au/ovidweb.cgi (Accessed 9 April 2004).

Lodge, G.M., Murphy, S.R. and Harden, S. 2003, 'Effects of grazing and management of herbage mass, persistence, animal production and soil water content of native pastures, *Australian Journal of Experimental Agriculture*, vol.43, pp.875-890.

Lovel, H. 2004, 'Pasture Management', in Acres Australia, vol.12, no.2, p. 21.

McDonough, B. 2000, 'How do you love ALL the children?', *Yes! Magazine*, Fall.

McNally, G. 2004, pers. comm., 15 June.

Mahon, L. 2003, 'The Power of Patterns', Journal of Permaculture Design Institute, vol.1, pp.4-5.

Martin, G. 2001 'Are there lessons from nature that can help us farm more sustainably and productively?' in *Proceeding of Property Management Planning Conference - Future Directions, Coffs Harbour, June 29, 2001*, North Coast Farming for the Future, pp. 14-21.

Mollison, B. 1992, *Permaculture, A Designers Manual*, 1st edn, Tagari Publications, Tyalgum, NSW.

Mostert, E. 2003, The European Water Framework Directive and water management research, Physics and Chemistry of the Earth, Parts A/B/C, vol. 28, no. 12-13, online. Available http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6X1W-49097R3-2&_user=10&_handl (Accessed 16 April 2004).

The National Association for Sustainable Agriculture Australia Limited, *The Standards for Organic Agricultural Production*, Amended September 2002, The National Association for Sustainable Agriculture Australia Limited, Stirling, South Australia.

Petrik 2003, Quotes from Understanding the Soil Processes. Available http://www.petriklabs.com/PUBLIC/library/ups.html.

Podolinski, A. 1985, 'Lecture 1', in *Biodynamic Agriculture: Introductory Lectures*, vol.1, Gavemer Foundation, Sydney, pp. 17-27, reprinted in the module Thinking About Soils – issues and debates, Collected Readings, 2001 edition, collected by D. Hodgkins, B.Baldwin and K.Cochrane, Faculty of Rural Management, The University of Sydney, Orange, NSW.

Sait, G. 1998, General Guidelines and Operating Principles, online. Available at http://www.nutri-tech.com.au.

Sait, G., Zimmer, G. and Brunetti, J. 2003, 'The Three-Up Tour, Nutrition Farming Explained', Workshop Manual, March 18-April 8.

Salatin, J. 1995 *Salad Bar Beef*, 1st edn, Polyface, Inc., Swoope, Virginia.

Savory, A. 2003, ‘Ecosystems breaking down’, The Land, 12 June, p.9.

Sayre, L. 2004, ‘New finding: Organic farming combats global warming’, The New Farm, online. Available http://www.newfarm.org/depts/NFfield_trials/1003/carbonsequest.shtml (Accessed 3 February 2004).

Schnitzer, M. and Kodama, H. 1975, *Geoderma*, vol.13, p.279.cited in Stevenson, 1994

Suzuki, D. & Dressel, H. 2002 *Good News for a Change – Hope for a Troubled Planet*, 1st edn, Stoddard Publishing Co. Ltd., Toronto.

Tan, K.H. 2003, *Humic Matter in Soil and the Environment: Principles and Controversies*, 1st edn, Marcel Dekker, Inc., New York.

Turner, P.E. 1932, ‘An analysis of factors contributing to the determination of saturation capacity in some tropical soil types’, *Journal of Agricultural Science*, vol.22, pp. 72-91.

United Nations Environment Programme, ‘Our present course is unsustainable – postponing action is no longer an option’, Nairobi, Press Release, online. Available http://www.uneporg/geo2000/presre/index.htm

Waksman, S.A. 1936, Humus: Origin, Chemical Composition and Importance in Nature, 1st edn, Bailliere, Tindall and Cox, Covent Garden, London.

Warren, S.D., Blackburn, W.H. and Taylor, C.A. 1986, ‘Soil Hydrologic Response to Number of Pastures and Stocking Density under Intensive Rotation Grazing’, *Journal of Range Management*, vol.39, no.6, pp.500-504.

Waters, A.G. and Oades, J.M. 1991, ‘Organic matter in water stable aggregates’ p.163-174. In: W.S. Wilson (ed.), Advances in Soil Organic Matter Research: The Impact on Agriculture and the Environment, R. Soc. Chem., Cambridge.

Wedekind, E. and Garre, G. 1928, ‘Die Kolloidnatur der Ligninsaure und des Kasseler Brauns’, *Kolloid Ztschr*, vol.44, pp. 205-212.

Wheeler, P.A. and Ward, R.B. 1998, The *Non-Toxic Farming Handbook*, 1st edn, Acres, U.S.A., Louisiana.

Whitbread, A.M., Lefroy, R.D.B. and Blair, G.J. 1996, ‘Changes in Soil Physical Properties and Soil Organic Carbon Fractions with Cropping on a Red Brown Earth Soil’, in *Proceedings of the 8th Annual Agronomy Conference*, Toowoomba, Department of Agronomy and Soil Science, University of New England, Armidale, NSW.

Williams, J. 1991, Search for Sustainability: Agriculture and its Place in the Natural Ecosystem, *Agricultural Science*, March, pp.32-39

Wollny, E. 1897, Die Zersetzung der organischen Stoffe und die Humusbildung mit Rücksicht auf die Bodenkultur, Heidelberg.1897 cited in Waksman,

Xiong, S.G. and Cheng, C.Y. 1991, 'Effects of ploughing-in green manure on the humus forms and physical properties of sandy meadow soils', Acta Agriculturae Universitatis Pekinensis, vol.17, no.3, pp.58-61, online. Available http://80-gateway1.ovid.com.opac.library.usyd.edu.au/ovidweb.cgi (Accessed 9 April 2004).

Yencken, D. and Wilkinson, D. 2001, *Resetting the Compass – Australia's Journey Towards Sustainability*, 1st edn, CSIRO, Collingwood, Victoria.

Zimmer, G.F. 2000, *The Biological Farmer: a complete guide to the sustainable and profitable biological system of farming*, 1st edn., Acres U.S.A., Austin, Texas, U.S.A.