Certificate in Sustainable Agriculture

ACHIEVING SUSTAINABLE AGRICULTURE IN AUSTRALIA

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Welcome

Thank you for purchasing this course. Over the last few years we have formulated this course so anyone can understand the fundamentals of sustainable agriculture. I am sure it will enjoy and get great value out of the course.

Kind regards

Timothy Lester

CEO – BioStim Pty Ltd
BAppSc(Hons) Rural Technology – Agronomy University of Queensland.

How to Use This Course

- Read the material and take notes if needed.
- If there are any words where you are not sure of the understanding please refer to glossary at the end of each chapter.
- At the end of each chapter there are multiple choice questions and answers. Please complete the chapter questions and check the answers at the end of the course book before preceding to the next chapter. If any questions are wrong you can re-read those chapter parts to understand why if necessary.
- Once you have read the course and answered all the questions you can then display the certificate.

Dedicated and Team Effort

I would like to thank Dr Bernie Wills for teaching me soil chemistry but more importantly the tools to learn and teach others. This course is a team effort from people all over the world and I would like to thank you all.

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INTRODUCTION

The importance of agriculture is self-evident because its viability is required for feeding millions of people. Australia has been fortunate to have had a well-established, technologically advanced and highly productive agricultural industry for many decades. However, Australia is generally a land with poor soils and harsh weather conditions, so farming has had and still has many natural challenges. Added to that, in the effort to grow more and more food on shrinking areas of good farmland, unsustainable practices in agriculture have become common. For example, heavy soil use has caused erosion where the valuable topsoil and its nutrients have been blown and washed away.

Soils have become saline and too acidic for crops to grow. Nitrogen fertilisers have been oversupplied and that has led to groundwater contamination, and phosphate fertilisers have been added in such huge amounts that they have become bound in soils in huge quantities. The heavy use of pesticides and other chemicals have polluted soils as well as waterways and adjacent crops. The reliance of farming on fertilisers and petroleum fuels has sharply increased costs and has made agriculture vulnerable to the shrinking worldwide petroleum reserves. So the obvious question is: “How can agriculture become more sustainable?” This course not only addresses the problems faced in Australian agriculture and provides some excellent remedies, especially from the standpoint of soils and their health, but also very importantly how better practices can be employed to make agriculture more sustainable without sacrificing profit. Altruism is commendable, but at the end of the day, growers must also be able to earn a decent living. We hope that you benefit from this course and also obtain pleasure and satisfaction from the learning process.

CHALLENGES OF LAND USE

LAND DEGRADATION IN AUSTRALIA

Australia is a big country, but the major part of it is not suitable for farming. Australian farmers have at their disposal the oldest, most worn-out and problematic soils in the world. Australian soils are frequently timeworn, infertile, degraded and saline. There are inherent problems such as the serious and continuing structural decline of the soils. The highest food producing areas are shrinking every day and experts are calling it a national disaster. Part of the problem has been inherited from harsh natural environments such as frequent cycles of droughts and floods, but we are also aggravating the problem by unsustainable soil management practices. According to Woods (1983) and Mabbutt (1992) the land degradation of cropland in Australia as shown in the following table is alarming:

LAND DEGRADATION ON CROPLAND IN AUSTRALIA	
TYPE	**AREA** (‘000 KM^2)
Total area	443
Undegraded	142
Degraded	301
DEGRADED BY:	
i. Water erosion	206
ii. Wind erosion	52
iii. Combined water and wind erosion	42
iv. Salinity and water erosion	0.9
v. Others	0.5

Agriculture experts consider land degradation in terms of the depletion of actual or potential productivity because of natural and anthropogenic factors, i.e. it is the decline in land quality or reduction in its productivity. In the context of productivity, land degradation results from a mismatch between land quality and land use (Beinroth *et al.*, 1994). Mechanisms that initiate land degradation include physical, chemical, and biological processes (Lal, 1994).
Important among physical processes are a decline in soil structure leading to crusting, compaction, erosion, desertification, anaerobic conditions, environmental pollution and unsustainable land use. Significant chemical processes include acidification, leaching, salinisation, decrease in cation retention capacity and fertility exhaustion.

Degraded soil

Eroded soil

Dr. John Williams, Deputy Chief of CSIRO Land & Water said:
"The bottom line is that it is very clear there has been significant damage to the nation’s soil resource, due mainly to farming, forestry, horticulture and other forms of development…"
He says that the greatest problem facing Australia’s soils is structural decline, leading to falling agricultural productivity.

The next greatest threat is acidification of soils, a serious problem because Australian farming practices are significantly aggravating this. Land cleared of native vegetation tends to go acidic at a rate of about one pH unit every 35 years, so with the passage of time some soils will become too acidic for crops to grow.

Erosion caused by wind and water is another common problem, particularly in parts of Western and South Australia.

Salinisation of Australian soils is also a serious problem, costing at least $300 million a year to the nation.
Another major threat to the nation's soil resource is its nutrient decline. The present farming processes are literally mining precious nutrients, particularly nitrogen and phosphorus, at an unsustainable rate, especially in parts of the rich clayey lands of northern NSW and Queensland. Therefore, one can easily comprehend the continued risk of impairment to one of the world's poorer soil resources.


Salt pan


Exhausted soil

GLOSSARY

Anaerobism/Anaerobic---lacking oxygen.
Anthropogenic---of human origin or stemming from human processes.
Biological process---changes caused by such agents as bacteria or worms.
Chemical process---changes caused by such agents as bicarbonate in water.
Compaction---hardening of soil.
Crusting---the top layer of soil becoming very hard.
Degradation---processes whereby land gradually becomes less productive.
Erosion---good soil is removed by agents such as wind or water.
Horticulture---cultivating vegetables, fruits, flowers and ornamental plants.
Infertile---soil does not support adequate plant growth.
pH---measure of a soil's acidity (lower value) or alkalinity (higher value).
Physical process---changes caused by such agents as wind and water.
Saline/Salinisation---salts in soil.
Salt---a chemical composed of separate units such as sodium and chloride ions (ions are atoms that contain an electric charge).

QUESTIONS

1. Are old, worn-out soils common in Australia?
   a. Not very common
   b. Yes, old, worn-out soils are common in Australia
   c. No old worn out soils exist in Australia
   d. Old soils are there but not worn out

2. Is land degradation a serious problem in Australia?
   a. No, it is a problem but not very serious
   b. Land degradation is not a serious problem in Australia
   c. Yes, land degradation is a serious problem in Australia

3. What are the three main mechanisms that initiate land degradation?
   a. Physical, chemical and biological processes
   b. Physical process, biochemical processes, environmental process
   c. Chemical process, non-chemical processes, biochemical processes
   d. Biological process, land use processes, crop harvesting processes
   e. Agronomic processes, horticultural processes, botanical processes

4. What are three physical processes of land degradation?
   a. Floods, Wind erosion, Drought
   b. Decline in Soil Structure, Compaction, Erosion
   c. Tillage practices, irrigation, Plant protection

5. What are two chemical processes of land degradation?
   a. Acidification and Salinisation
   b. Acidification and Alkalization
   c. Low pH and Fertilization

6. At what rate does cleared native land become acidic?
   a. 3 pH units every 10 years
   b. 2 pH units every 20 years
   c. 1 pH unit every 35 years

7. Are current farming systems mining (depleting) nutrients at an unsustainable rate?
   a. Yes
   b. No
   c. To some extent

WHAT IS SOIL?

> **"Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together."**
> *Charles E. Kellogg, USDA Yearbook of Agriculture, 1938*

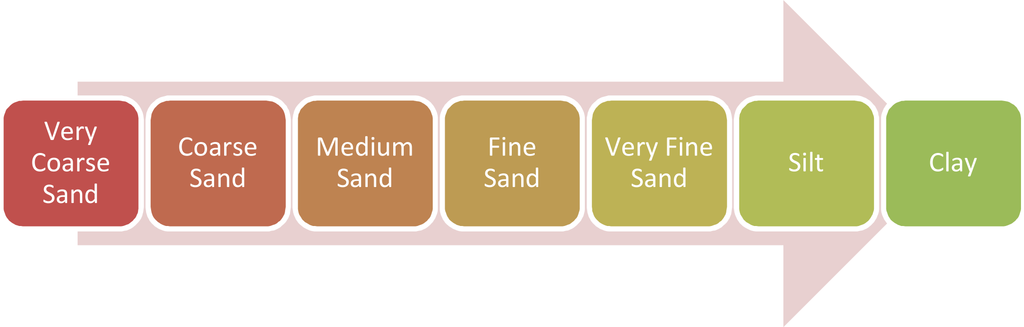
SOIL COMPONENTS

The earth's surface is covered by a thin material composed of many components like weathered rock and decayed plant and animal matter that permits the vegetative growth on it. This we know as soil. Soil formation is the result of a multitude of interactions between air, water, plant life, animal life, rocks and chemicals. A soil that is acceptable for agriculture comprises about 50% porous spaces, 45% pulverized rock and 5% organic matter, which is the living skin of the planet. Rock is its parent material that generates the mineral, non-living matter, and organisms, both alive and dead, support the existence of interdependent life intricacies from the earliest stages of soil formation. When we speak of soil it is from the standpoint of a farmer or agricultural scientist who is justifiably concerned with the concept of sustainable agriculture. For sustainable agriculture a good soil has these qualities:

* Is grainy and crumbles easily with many peds.
* Has sufficient organic matter to warrant a good structure and insulation against extreme weather conditions.
* Does not crust after evaporation of surface moisture.
* Conserves rainwater and sufficient moisture for drought periods.
* Has a minimum number of clods.
* Has no hardpan deep down in the profile.
* Resists erosion.
* Holds nutrients well.
* Supports high populations of macro and microorganisms.
* Has a rich, earthy smell.
* Does not require increasing fertiliser inputs for high yields.
* Produces pest resistant, high yielding crops.

Soil texture with respect to particle size falls in categories from course to fine. The US Department of Agriculture has established various texture categories in diameter ranges (mm) as follows:

Clay	<0.002
Silt	0.002–0.05
Very fine sand	0.05–0.10
Fine sand	0.10–0.25
Medium sand	0.25–0.50
Coarse sand	0.50–1.00
Very coarse sand	1.00–2.00



Weathering of rock

Rock turns to soil

SOIL BUILDING PROCESS

Soil building begins with the physical and chemical disintegration of the parent material. Mechanical weathering and temperature changes play their role in pulverizing primal rocks. Other soil making agents are acid deposition and oxidation. The type of parent material and climate variations decide the type of soil that evolves. Another essential soil making factor is detritus that comes from decaying plants and animals. Through the process of detritus formation inorganic nutrients become more soluble and thus become available to plants, and the pH of soils is optimised. Detritus also improves soil structure, thus permitting aeration and increasing the soil's water holding capacity. How long does it take to produce soil? Scientists have many estimates, but believe that nature takes 200 to 1000 years to create 16.4 cm^3 (=1 cubic inch) of topsoil. This soil formation process undergoes three stages.

Stage One:

During the first stage forces of wind, rain and temperature extremes that cause water to freeze and thaw work together to pulverize rocks. Earthquakes and volcanoes also play their role and soil consisting of sand, silt and clay particles emerges. This mineral soil is not capable of supporting life because it lacks ammonia or nitrate.

Stage Two:

Soil enters the second stage when cyanobacteria and biological soil crusts show up. Cryptobiotic soil utilizes cyanobacteria to invoke the initial flush of life. These bacteria are also known as blue-green algae and are the main components of the biological soil crust. These remarkable bacteria are a big part of what makes life possible on planet earth. There is evidence that cyanobacteria were largely responsible for shifting the earth's atmosphere from high in carbon dioxide to rich in oxygen.

Filaments of *Microcoleus vaginatus* are the main organism in the crust. The Cryptobiotic soils played an important role in creating the air on the earth and this second stage of Cryptobiotic soils takes hundreds of years to achieve.

Lichens also begin their struggle to exist during this stage. When an alga and fungus physically intertwine in a close symbiotic relationship they form a new growth known as lichen. Lichen is a type of very old plant species that is nothing more than strands of algae intertwined with hyphae of fungi that together absorb minerals from soil and commence the process of photosynthesis. Lichens can grow almost anywhere, from moist tree bark to cooled lava and many other types of rocks. Lichens may live for thousands of years and they degrade rocks with acids that they produce. They still cover more than 8% of the earth's surface.

Cyanobacteria under a microscope

Lichens degrading rock

Stage Three:

During this stage little pockets of soil start forming sporadically to permit root systems of larger plants to grow. The preliminary vegetation is short-lived as it makes ground for bigger plants with taproots that then build humus and soil horizons. Primitive vegetation is finally transformed into soil organic matter and this in combination with soil mineral particles contributes to the following:

* Enhanced soil aggregation (peds).
* Increased structural stability.
* Increased water holding capacity.
* Better nutrient holding capacity.
* Buffering against acidification.
* Binding toxic substances to the soil, e.g. excess Al and F.

Grasses appear first **Trees appear later**

IMPORTANCE OF SOIL TEXTURE AND STRUCTURE

The texture and structure of a soil determines pore space for air and water circulation, erosion resistance, looseness, ease of tillage, and root penetration. While texture pertains to the size of soil particles, it also indicates some chemical properties of the minerals in the soil. Soil texture does not easily change with agricultural activities, but structure can be improved or destroyed readily by farm practices. A good soil needs to be soft, drain well, store moisture, be rich in nutrients, support soil organisms, soak up rain, resist erosion and warm up quickly to produce healthy crops. By understanding the principles of maintaining native soils, farmers can develop and sustain productive and profitable soils for future generations as well. The soil benefits when its natural productivity and texture is managed in a sustainable way. Natural processes are the best way to manage soil and produce crops and animals that are healthy and productive.

Soils are made up of four basic components: minerals (45%), air and water (25%) and organic matter (2% to 5%). The mineral portion consists of sand, silt or clay. Sand is largely the mineral quartz, though some other minerals are also present. Sand cannot hold nutrients as they leach down easily with rainfall. Silt, like sand, is mostly quartz. The smallest of all the soil particles is clay and it is quite different from sand and silt. Clay is the fraction that contains appreciable amounts of plant nutrients and has a large surface area resulting from the plate-like shape of the individual particles. Sandy soils are less productive than silts, while soils containing clay are the most productive and make the most efficient use of fertilisers.

Soil texture refers to the relative proportions of sand, silt and clay. Sandy textures have 90-100% sand. Soils with more than 35% clay are called clays because they have common features such as stickiness. Soils that have about 20-30% clay and roughly equal amounts of silt and sand are loams. Therefore, a loam soil contains the three types of soil particles in roughly equal proportions; a sandy loam is a mixture containing a larger amount of sand and a smaller amount of clay, while a clay loam contains a larger amount of clay and a smaller amount of sand.

Another soil characteristic is known as soil structure and this is distinct from soil texture. Structure refers to the clumping together or "aggregation" of sand, silt and clay particles with organic matter into larger secondary clusters called peds. One can determine a good soil structure by grabbing a handful of it and feeling if it crumbles easily in the hand.

If it crumbles easily this indicates that the sand, silt, and clay particles plus organic matter are well aggregated into granules or crumbs.

GLOSSARY

Aeration---providing oxygen.
Ammonia---chemical compound composed of nitrogen and hydrogen.
Buffering---resisting change.
Cryptobiotic---microbes, insects or animals living in concealment.
Decayed---destruction of plant matter such as rotting.
Detritus---disintegrated matter.
Humus---decaying plant and animal matter.
Hyphae---thread like extensions of fungi that obtain nutrients.
Lava---volcanic rock.
Macroorganism---Larger organisms such as ants, termites, insects and earthworms.
Microorganism---Smaller organisms such as nematodes, bacteria, microscopic fungi and algae.
Nitrate---chemical compound composed of nitrogen and oxygen.
Organic matter---derived or coming from living things.
Oxidation---process by which oxygen is added (e.g. rusting of iron).
Peds---individual, natural aggregates of soil particles.
Pest---insect or other organism or disease that harms crops.
Porous---containing many holes.
Photosynthesis---process of converting carbon dioxide and water into glucose (a sugar).
Quartz---common white/yellowish mineral.
Symbiotic---a relationship between organisms (usually two) where each benefits from the other.
Tillage/Tilling---breaking up of soil, e.g. by ploughing.
Weathered rock---rock that has been broken into smaller sizes by wind and rain.
<---means less than.
>---means greater than.

QUESTIONS

1. What processes occur in the first stage of soil building?
   a. Processes of wind, rain, earth quakes, and temperature extremes on rocks
   b. Volcanic and Climatic processes
   c. There are no processes in the first stage of soil building.

2. What bacteria/algae are involved in the second stage of soil building?
   a. Lactic Acid Bacteria
   b. cyanobacteria and lichens
   c. Only algae are involved in the second stage of soil building.

3. In the third stage, what soil properties does organic matter enhance?
    a. Soil Structure
    b. Water holding capacity of soil
    c. Buffering against acidification
    d. Nutrient holding capacity
    e. Binding toxic substances to the soil
    f. All above (a, b, c, d, e)

4. What are the four basic components of soil?
    a. Water, Calcium, Sodium and Sand
    b. Sand, Clay, Organic matter and Water
    c. Mineral, Air, Water and Organic matter
    d Calcium, Aluminum, Nitrogen and Phosphorus

5. Sand is composed mainly of what common mineral?
    a. Copper
    b. Zinc
    c. Quartz
    d. Boron
    e. Magnesium

6. Silt is composed mainly of what mineral?
    a. Manganese
    b. Iron
    c. Copper
    d. Quartz
    e. Zinc

7. Does clay hold appreciable amounts of nutrients?
    a. Clay hold a little nutrients
    b. Clay does not hold nutrients
    c. Clay holds appreciable amounts of nutrients

8. Does sand hold appreciable amounts of nutrients?
    a. Sand holds appreciable amounts of nutrients
    b. Sand does not hold appreciable amount of nutrients

9. What is the composition of loam?
    a. Loam is 20-30% clay and roughly equal amounts of silt and sand
    b. Loam is 50% clay and 50% Sand
    c. Loam is 30% clay and 70% Sand
    d. Loam is 20% clay, 40% Silt and 40% Sand