This paper will discuss conventional soil management techniques in Australia and then will compare them to soil management techniques in the tropics in order to have a better understanding of agricultural techniques on the Fijian island of Taveuni. This personally relates to agricultural projects that I have and will continue to be working on with indigenous Fijians on Taveuni.

Background to the island of Taveuni

- Part of the Fijian Island group of 332 island;
- Third largest island (after Viti Levu and Vanua Levu)
- Known as the "Garden Island of Fiji" providing a considerable amount of Fiji's staple crops such as coconuts, taro, cassava, kava, pineapples and tropical fruits;
- Volcanic island, one of the newest islands in the Fijian group, reportedly only 2,000 years old;
- Trade winds bring high rainfall through out the year averaging about 2600mm per annum. [*Source: Fijian Meteorological Bureau- Oct 14 2003]*
- Climate is warm humid,(with humidity ranging from 78%-83% average [*Source: Fijian Meteorological Bureau- Oct 14 2003*] sub-tropical, lowland and montane rainforest

CLIMATIC FEATURES OF HUMID TROPICS AND SUBTROPICS ZONES

Taken from *www.fao.org - Chapter 1- The Tropical Environment*

This climate zone is characterised by high temperatures throughout the year and only a short to very short dry season, and is typical of some 1 925 million ha, mainly located in central and coastal West Africa, the Amazon basin, Southeast Asia and the islands of the Pacific Ocean.

The long growing periods combined with high temperatures are conditions that favour tropical rain forests, and also allow agricultural activities all year round, although high rainfall at harvest time and flourishing pests and diseases may be a moderate constraint. The rather unfavourable temperatures hamper grazing.

Soil Composition of Taveuni

- Relatively new fertile dark brown volcanic soil
- Mixture of rich alluvial soil (in the lowlands) and high level of pumice and other volcanic matter
- Some organic matter present as the “bush” often lays fallow and minimal cultivation practices (no-till) of the locals.
- Low to Medium crusting of soil surface after heavy rain
- Soil relatively well draining even after heavy rains (This may also be due to the humidity and the evaporative effect of the sun).
- High presence of ladybird beetle, beneficial predatory insect, indicating an active and thriving eco-system

CONVENTIONAL SOIL MANAGEMENT IN AUSTRALIA

Conventional soil management includes

- Clearfell land clearing → siltation, topsoil loss, erosion and salinity
- Logging → erosion, change in weather patterns, habitat loss
- Limited contour ploughing → inefficient water run-off, topsoil loss, → erosion and land slippage
- Traditional tilling methods → loss of topsoil → erosion → dust storms and high level of disturbance for micro-organisms

- Overgrazed pastures → desertification and soil compaction
- Overuse of fertilisers → increased phosphate levels → blue-green algae outbreaks
- Overuse of pesticides, herbicides and fungicides → need to understand ecology and environment more to provide natural sources of pest reduction. E.g. using the dung beetle (both native and exotic) to reduce the amount of cow dung → decrease fly population
- Soil fumigation → methyl bromide (greenhouse gas) → sterile soil and long term residue
- No or limited rotation of crops
- Huge reliance on monoculture (single varieties of crop), often leading to pest infestations and a reduced strain leading to susceptibility to attack and low crop yields over time.

TRADITIONAL FARMING SYSTEMS IN THE TROPICS

Taken from *www.fao.org Chapter 2- "Predominant farming systems of the tropics"*

- Have not changed much since the early 20th century.
- Shifting cultivation and bush fallow rotation are widely used.
- Subsistence systems are diverse and based on low inputs
- Several crops are grown simultaneously on the same piece of land
- In some regions, traditional "slash and burn" farming practices have been destructive and has caused severe soil and environmental degradation, especially on marginal or steep lands.
- Runoff and erosion are generally reduced if the fallow period is long enough to restore soil properties and increase soil organic matter content.

"Traditionally, farmers abandon the land when crop yields are too low either because of prevalence of pests or because of deterioration in soil quality. The rate of decline in crop yields on soils under traditional farming depends on many factors- soil properties, crops grown, prevalent climate and soil management techniques." [1]

Studies in East Africa (Allan [1965]) indicated that soils of inherent fertility, it took 20 years of continuous cultivation to cause severe yield decline. On soils with low fertility, yields declined under traditional farming in 1-2 years.

It is interesting to note that "in most of the lowland tropics with sparser population and relatively fertile soils, traditional [farming] systems have proved to be ecologically stable despite the minimal inputs of the shifting cultivators" [2].
This system is ecologically stable and works as long as the farmers are willing to remain at the subsistence level.

OTHER FARMING SYSTEMS IN THE TROPICS

Cropping and farming systems that have been tried as alternatives to shifting cultivation and bush-fallow rotations include:

Large-scale mechanised farming

- Mechanised farming has been tried widely in Africa, with limited success.
- Major problems occurring in intensive cropping include soil compaction, accelerated erosion and low soil fertility. This sounds very similar to the scenarios faced in Australia by farmers.
- Mechanised harvesting is particularly damaging if the soil is wet.

[1] *www.fao.org Chapter 2- "Predominant farming systems of the tropics"*
[2] *ibid.*

Ranching and pasture development

- Ranching is popular in the humid tropics.
- Intensive pasture development is successful only when the initial soil fertility is high and the stocking rate is carefully managed.
- Excessive and uncontrolled grazing depletes the vegetation cover, changes the species composition, exposes soil to high-intensity rain, compacts the surface soil layer and decreases the infiltration rate of the surface soil layer. It can cause at least as many problems as mechanised farming.

Forestry

- Tree based farming systems are very common in the humid tropics.
- Generally believed that forest plantations and tree crops can provide ecologically stable systems.
- With careless management, severe soil compaction and accelerated soil erosion and land degradation occur.
- Plantations make heavy demands for plant nutrients on the soil, but with good management the chances of attaining ecological compatible systems are better with trees than other crops.
- Tree crops protect the soil against raindrop impact and sun exposure (insolation) by their continuous cover.

Tree crops are key components of some agricultural production systems. These include:

- Fruit and nut orchards
- Plantations yielding oil, rubber, gums, tannins and drugs
- Forest plantations providing timber and forest related products
- Trees and shrubs naturally maintained or planted fallow to recycle nutrients for other arable crops
- Trees grown with food crops for animal husbandry.

TILLAGE SYSTEMS

Tillage can be defined as "*embracing all operations of seedbed preparation that optimise soil and environmental conditions for seed germination, seedling establishment and crop growth.*" [3]

It includes:

- Mechanical methods based on conventional techniques of ploughing and harrowing
- Weed control using chemical herbicides and growth regulators
- Fallowing with an aggressive cover crop that can be easily controlled for direct seedling through its residue mulch.

There are a wide range of tillage systems used in the tropics, which primarily include the following:

Traditional Tillage

- Weeds and bush regrowth is slashed manually (using machete or brush-cutter) and left on the soil as mulch or is burnt on site.
- Land is then hand-hoed, often lightly
- Farmers also make mounds or ridges, often with manually operated hoes or equipment drawn by draught animals.
- Mounds, ridges and other forms of raised beds are widely used throughout the tropics

[3] *www.fao.org Chapter 3- "Tillage systems"*

- Farmers often mulch the mounds with crop and weed residues.
- Mixed cropping provides a continuous ground cover that protects the soil against erosion and improves soil temperature and moisture holding capacity.
- Mound building is also useful in concentrating nutrient-rich surface soil.
- With the native method of cultivation, mounding is clearly beneficial, especially when mixed cropping is practiced with little or no fertiliser input.
- On some shallow soils, crops are grown in depressions rather than mounds (very similar to European style) to help conserve water and minimise the effect of the drought.

The practice of mound building is slightly superior to a mulched flat seedbed on which in-organic fertilisers have been applied

Plough-Till

This system is based on mechanical soil manipulation of an entire field, and involves mouldboard ploughing followed by one or two harrowings.

- Embraces primary cultivation method of ploughing or soil inversion. Secondary cultivation using discs and tertiary working by cultivators and harrows.
- Can be mechanised or drawn by draught animals
- Can increase (esp. mechanised soil disturbance) the risk of erosion by removing the vegetation cover and exposes the soil to rainfall, wind and overland flow.
- However this technique gives a weed-free seedbed, incorporates fertiliser and can also inprove soil conditions.
- The effects of erosion vary depending on basic soil properties. Where the soil has favourable structure with a high proportion of water-stable aggregates and is permeable, mechanical soil disturbance is likely to increase the risk of soil erosion. However, where the soil has a smooth crusted surface and compacted subsoil horizons, massive non-porous unstable structure, carefully judged, timely mechanical tillage is likely to decrease the risks of soil erosion, at least temporarily.

Conservation Tillage (CT)

Wittmus et al. (1973) has described Conservation Tillage as *"a tillage system that creates as good an environment as possible for the growing crop and that optimise the conservation of soil and water resources, consistent with sound economic practices."*

However the term encompasses a broad spectrum of practices ranging from no-till to intensive till, depending

Qualifying Criteria for Conservation Tillage

FAO (*Chapter 3- Tillage Systems*) describers the criteria to be met for a method of seedbed preparation to be considered as conservation tillage to include:

- the presence of a crop residue
- effective conservation of soil and water
- maintenance of a high and economic level of productivity
- minimum need for chemical amendments and pesticides
- preservation of ecological stability
- minimum pollution of natural waters and environments.

With this definition in mind, the following practices can be labeled under the generic CT banner:

No-till or no-tillage system

- This is where the crop is "*planted directly into a seedbed that has not been tilled since the previous seedbed*." [4]
- The maximum amount of crop residue is retained on the surface.
- The weeds are controlled by chemicals, by residue mulch, by using an aggressive cover crop or by a combination of these methods.
- The disturbance of soil at harvesting, as in the case of root crops, can according to the definition of no-till system, still be classified as no-till.

Minimum Till (MT)

The term minimum-till has caused the greatest confusion because the minimum cultivation required to grow a crop successfully varies from zero to a complete range of primary and secondary tillage operations.
Minimum-till is therefore defined as *"the minimum soil manipulation necessary for crop production or meeting tillage requirements under the existing soil and climatic conditions."* [5] It often means any system that has few tillage requirements.

- Can also mean tillage of only part of the land, e.g. strip or zonal tillage
- MT may also refer to a "stale-bed" system in which the soil is ploughed at the end of the previous crop cycle. The crop is then seeded with a minimum of seedbed preparation performed at the onset of the next rains.

Mulch Tillage or stubble mulch farming

This is a broad term that refers to a tillage system that "*ensures a maximum retention of crop residue on the soil surface.*" [6]

- The soil is prepared in such a way that plant residues or other mulching materials are specifically left on or near the surface.
- It also includes practices such as no-till, disk plant systems, chisel plant systems and strip tillage systems.

Other terms used in mulch tillage include the following:

Sod seeding	When a grain crop is seeded through the mulch of a chemically killed cover crop.
Live mulch	When the crop cover is untreated or only temporarily suppressed.
Planted fallow	When a cover crop, usually a legume, is specifically grown within the cropping cycle to produce mulch material.
Summer fallow or *Ecofallow*	System of fallowing in which weed growth is restricted by shallow cultivation or by using herbicides to conserve soil moisture. Crops are grown every other year or once every three years. This method is mostly used in arid climates.

Mulch tillage is also practised in Agroforestry systems where alley cropping is widely used. This is where annual food crops are grown between widely spaced hedges of perennial shrubs. The hedges are planted on the contour and are regularly pruned to provide mulch.

Ridge Tillage

This is common practice throughout the tropics and sub-tropics. It is "*the practice of planting or seeding crops on ridges.*" [7]

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[4] www.fao.org *Chapter 3- "Tillage systems"*
[5] www.fao.org *Chapter 3- "Tillage systems"*
[6] *ibid*.
[7] *ibid.*

- Crop rows are planted on ridgetops, along both sides of the ridge or in furrows
- Facilitates mixed cropping systems
- Ridges may be made every season or alternatively in a semi-permanent environment, necessary repairs are conducted at the start of a new cropping cycle.
- Ridges may be on the contour with graded furrows draining into a grassed waterway

Tied ridge system Ridges that may have short cross-ties to created a series of basins to store water.

FACTORS AFFECTING THE CHOICE OF TILLAGE SYSTEMS

The choice of an appropriate tillage system for a given situation is based on the following factors: [8]

Climate

1. Erosivity
2. Temperature
3. Preciptiation

Soil Properties

1. Texture
2. Structure
3. Erodibility
4. Rooting depth
5. Slope
6. Organic Matter
7. Clay mineralogy
8. Iron and Aluminium oxides
9. Surface features including residual cover.

Crop Characteristics

1. Canopy characteristics
2. Duration
3. Root System
4. Water management
5. Soil conserving or degrading crop
6. Susceptibility to pests and diseases

Socio-economic factors

1. Farm size
2. Infrastructure
3. Marketing facility
4. Labour
5. Technology
6. Resources
7. Tradition or culture

Other socio-economic factors to consider include land tenure systems (tribal or freehold), credit availability, power sources, education, family structure and the role of women.

[8] Taken from *www.fao.org Chapter 3- "Tillage systems" figure 8*

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