Examination of the Process of Dryland Salinity

ENVIRONMENTAL RESEARCH & INFORMATION CONSORTIUM

Rising Groundwater Model (1)

- Has been officially presented as THE general model for dryland salinity
- Derives from observations of irrigation salinity where salinity occurs through an increased supply of water into the soil
- Also derives from general observations that dryland salinity was associated with tree clearing
  - it is assumed that tree clearing reduces evaporation and thereby effectively increases the supply of water into the soil similarly to irrigation

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Rising Groundwater Model (2)

- The rising groundwater model has many physical representations
  - Means different things to different people
  - It is seldom clear if the water moves vertically upwards or simply fails to drain away
- The description of the model has evolved to 'account' for discrepancies with observed outcomes
  - Initially the salt was said to derive from stores beneath the soil on the plains
  - The source of the salt is now given as being anywhere there are salt stores through which the water drains
  - Initially the lateral water flows were said to be in a groundwater system located beneath the soil
  - Flow pathways for water have been expanded to include lateral flow through soils
- The only constant has been the assertion that the cause is tree clearing on hills increasing the percolation of water into some form of groundwater system, usually discharging on plains

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Rising Groundwater Model (3)

- The definitions of groundwater are usually spurious
  - One has groundwater being all free water in the ground. Due to the inevitable occurrence of salt there is then no groundwater.
- The definitions almost invariably fail to discriminate between soil water and groundwater
  - soil water is harvested by plants
  - groundwater can be harvested by people
- Groundwater is usually modeled as the pore water that occurs beneath the root zone (beneath the soil)
- A general definition is that groundwater is the water that can be extracted from the ground without producing a non-zero matric potential
- Groundwater is effectively surplus soil water that cannot be utilised by plants

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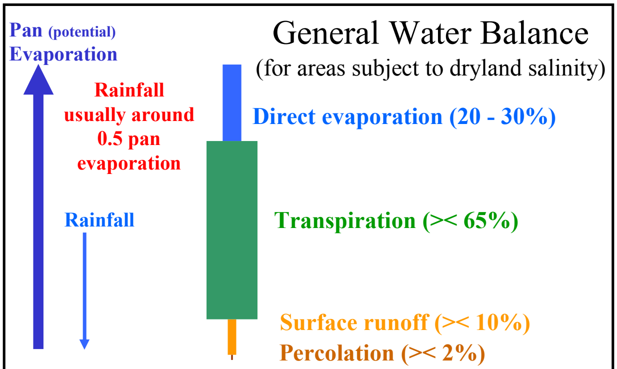
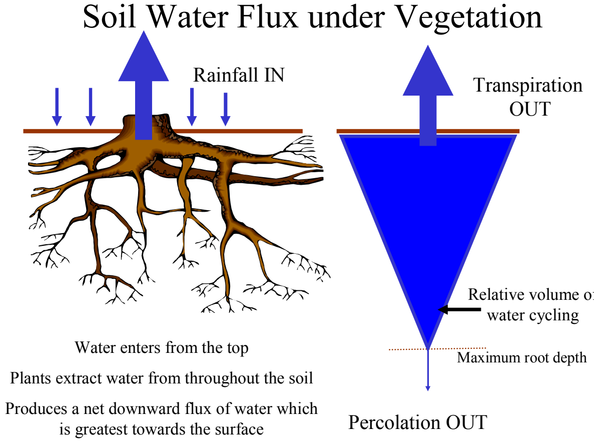
General Water Balance

(for areas subject to dryland salinity)



Percolation cannot be directly measured
Percolation << error in other measurements
Estimates of percolation are highly unreliable

Soil Water Flux under Vegetation

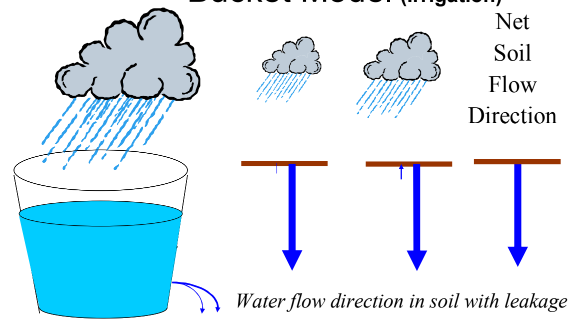


Models invoking increased water supply

The models examine the net direction of water flow for different constraints. While the diffusion of salt can be important most salt is mobilised by water flows. The net direction of water flow mainly determines the movement of salt.

- The first model reflects a bucket with some leakage
  - no lateral movement of water
- The second is a normal hill slope (landscape) with an assumed groundwater aquifer
  - landscapes do not necessarily have groundwater systems that interact with the local surface
- The third is a landscape with a confined groundwater aquifer

Bucket Model (Irrigation)

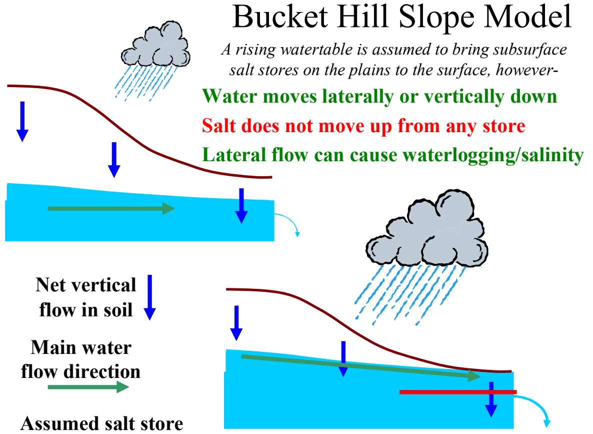


The net direction of water flow is down
A water level rise is not associated with an upward flow of water

Bucket Hill Slope Model

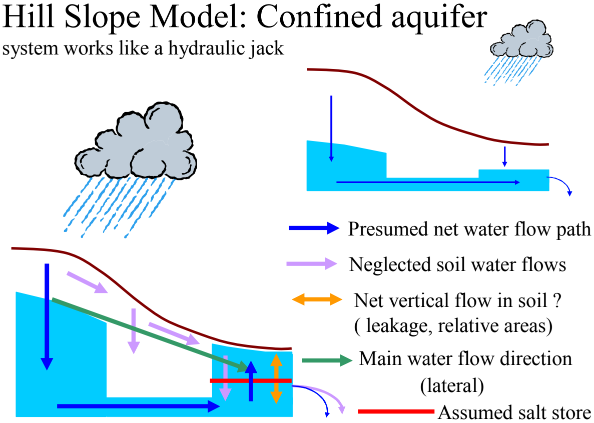
A rising watertable is assumed to bring subsurface salt stores on the plains to the surface, however-

Water moves laterally or vertically down
Salt does not move up from any store
Lateral flow can cause waterlogging/salinity



Hill Slope Model: Confined aquifer

system works like a hydraulic jack



Obvious Deficiencies in the Models

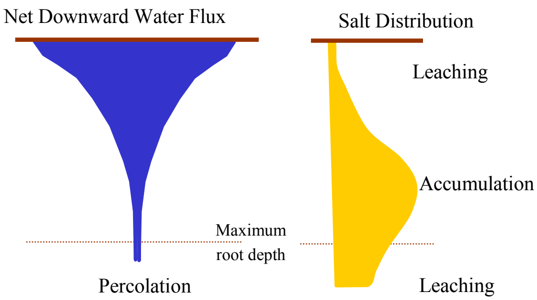
- No consideration of the land use impacts on soils
  - can invalidate the assumption that tree clearing increases the groundwater recharge
- No consideration of the surficial hydrology (plant - soil water relations) on the plains
  - does not address the downward movement of water on the plains
  - the plains are represented as a tub that fills from beneath
- Does not account for the common situation where there is no groundwater system that interacts with the surface
  - thick clay deposits often provide a seal under the soil and isolate it from any underlying groundwater systems

Role of Vegetation in Surficial Hydrology

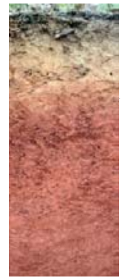
- Plants promote the leaching of salts from the surface soil by extracting water from the subsoil
- Plants promote the retention of nutrients and water in the surface soil by the production of organic matter
- Plants limit the leaching of salts (nutrients) from the soil profile by extracting water from the subsoil
  - Vegetation tends to maximise the utilisation of soil water and hence minimise the leaching of salts

Schematic Patterns

Net Soil Water Flux & Salt Distribution under Vegetation



Basic Soil Profile



A1 Accumulation of Organic Matter

A2 Leached

B1 Transition

B2 Accumulation of Clay & Ions

C Underlying parent material

(D Underlying non-parent material)

Salts are continuously leached from the surface and tend to accumulate in the subsoil ((B horizon).

Clays adsorb salt (can reduce the salinity of percolating water)

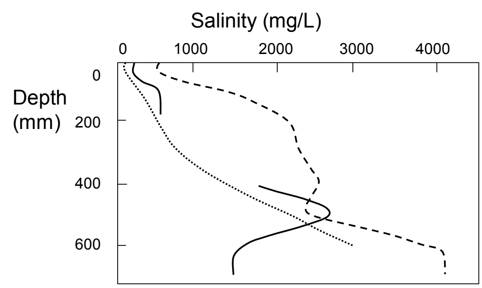
Salts can move up or down depending on patterns of water flow

Effects of Vegetation Degradation

- Reduced transpiration
  - Increased potential for percolation through the soil
  - Increased evaporation from the soil surface
- Soil degradation (reduced organic matter input, increased rate of loss of organic matter)
  - Decreased potential for infiltration and percolation (increases the surface runoff)
  - Increased salinity of the drainage water
  - Positive feedback in further degrading the vegetation and hence soil
- The insitu effect of decreased infiltration is for the accumulated salt to move closer to the surface because of the decreased leaching and increased evaporation from the soil surface

Observed Differences in Soil Salt Profiles

Soil salinity profiles for adjacent sites in natural woodland (———), 'normal' farmed land (- - - - - -) and land cultivated with an Eco-plow (···········), Tragowel Plain



Increasing the infiltration of water reduces the soil salinity

Plant Rooting Differences (lucerne)

Normal farming

Eco plough

Plant Rooting Differences (eucalypts)

Historic

Recent

(compacted soil layer)

Effects of Organic Matter on Soils

1. Increases the formation of soil aggregates
2. Greatly increases the water stability of the aggregates
3. From 1 & 2
   - increased permeability of the soil to air and water
   - reduced bulk density and hence increased depth
   - decreased susceptibility to erosion
4. Increases the ability to store cations (nutrients)
5. Tends to buffer the pH and thereby improve the ability of plants to take up nutrients
6. Increases the storage of water available to plants
   (possible exception is raw organic matter in heavy clays)

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Effects of Salts on Soils

- Very high levels of salt increase the aggregation of clay **regardless** of the composition of salts
- Low to moderate levels of salt (levels of consequence to plants) can increase or decrease aggregation depending on the cation
- Sodium (Na) strongly disperses clay which greatly:
  - Decreases the permeability of soil to air and water
  - Increases the susceptibility to erosion
  - Decreases the adsorption of nutrients
  - Decreases the ability of plants to take up nutrients
- Calcium (Ca) in particular, but most bi and tri valent cations, increase the aggregation of clay
  - A high proportion of Ca is usually good but a high proportion of Na is bad

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Soil Homogeneity / In-homogeneity

- Most models assume soils are vertically stratified (have horizons) but that the horizons are homogeneous (the soil properties of horizons can be characterised by mean or average conditions)
- Well structured soils are non-homogeneous within horizons due to fine structures such as aggregates (peds) and coarser structures such as cracks and old root channels
- In a homogeneous soil the entire profile has effectively to become saturated for percolation to occur
- In non-homogeneous soils percolation can occur along preferred pathways when the profile is only partially saturated

Percolation is greatest and more frequent in well structured soils

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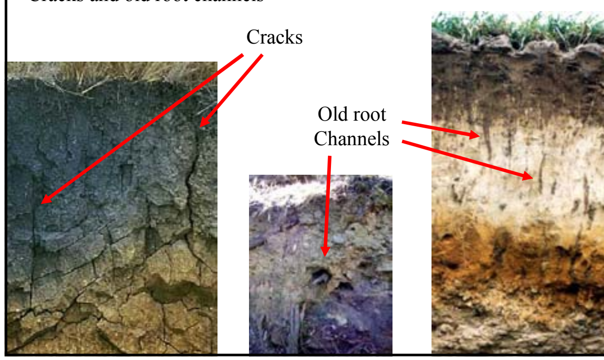
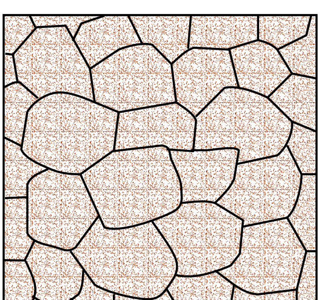
Preferred pathways for soil water flow (1)

Cracks and old root channels



Preferred pathways for soil water flow (2)

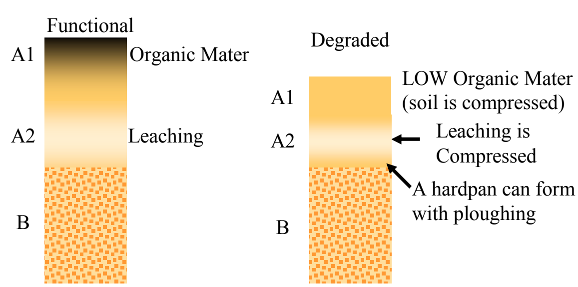
Schematic Diagram of Soil Peds



- Clays form aggregates termed peds
- Aggregation is determined by:
  - the type of clay
  - composition and level of salts
  - amount of organic matter
- Water flows in the gaps (cracks) between peds
- Salts accumulate in the peds
- Dispersing the clay (e.g. with Na) can eliminate this preferred pathway for water flow.
  - Water flow is reduced and the residence time for water is increased
  - The salinity of the water increases

Schematic Representation of Soil Degradation

The loss of organic matter produces compaction of the A horizon which reduces infiltration and thereby leaching of the A2 horizon.



Salinity Consequences of Preferred Pathways for Water Flow (1)

- The salinity of water flowing along preferred pathways is not in equilibrium with the soil
  - (has lower salinity than the soil generally)
- Removing preferred pathways
  - Decreases the permeability of the soil to air and water
  - Increases the bulk density
  - Increases the susceptibility to erosion
- Soil degradation
  - Increases surface runoff
  - Decreases infiltration of water into soils and percolation through them
  - Increases the salinity of the drainage water

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Salinity Consequences of Preferred Pathways for Water Flow (2)

- Adverse soil salinity can arise insitu because of the reduced percolation
- Most severe adverse salinity arises where soil water drains laterally and accumulates at a lower position in the landscape
  - Salinity of the drainage water is increased by the decline in soil structure
  - Evaporation increases the salt concentration of the accumulated water (waterlogging is often a precursor of salinity)
- Coarse structural features of the landscape affect patterns of water flow and accumulation
  - coarse structures moderate dryland salinity

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Analogy Description of Preferred Pathways

Analogy: a road system of freeways, major and minor roads and tracks

- Most soil water in natural systems flows along freeways.
  - It moves quickly through the soil and contains little salt.
- With soil degradation the freeways and roads become blocked and the water moves slowly along minor tracks.
  - Due to the slow movement the water takes up salt from the soil
- As freeways provided rapid movement through the soil
  - Loss of freeways reduces percolation to groundwater systems
  - Loss of freeways increases the lateral flow in the soil
- The net effect is to increase surficial lateral flow of water and to increase the salinity of the water

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Climatic Constraints to Dryland Salinity

- Dryland salinity is most common in areas with Mediterranean climates
  - Low rainfall relative to evaporation limits leaching of salt from the system
  - Occurrence of rain during periods of low evaporation (winter) promotes soil saturation and hence drainage
  - High evaporation over summer concentrates the salt where drainage water accumulates
- Dryland salinity does not occur where rainfall is sufficient to regularly leach salts from the soil (ie, where there is a high level of percolation of water through soils)

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Soil Constraints to Dryland Salinity

- Saline soils tend to be clays or loams with low to moderate permeability
- Highly permeable soils (e.g. sands) are seldom subject to adverse salinity
  - Salts tend to be leached
- High organic soils tend not to be saline (mangroves and marine couch grasslands excepted)
  - A function of climate as well as permeability and the location of organic matter in the soil

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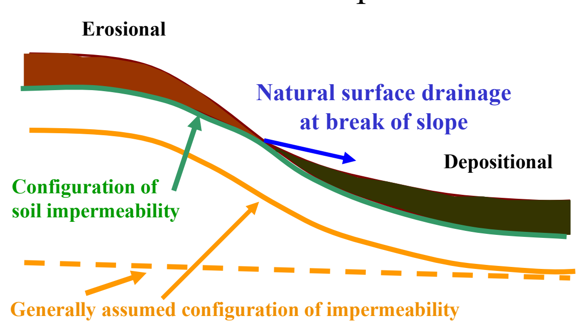
Standard Landscape Model



This model forms the basis for Soil Landscape Mapping

Forms of Expression of Dryland Salinity

- The mechanism for dryland salinity is addressed in papers on the ERIC web site
  - Scenario for dryland salinity
  - What model for dryland salinity
- Both papers have dryland salinity arising from changes to hydrology arising from changes to vegetation and soil structure
- The second paper identifies that realised outcomes depend on structural features of the landscape
- The following examples illustrate different expressions of dryland salinity associated with differences in geomorphic constraints

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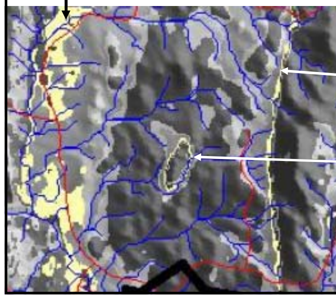
Expression of Dryland Salinity

Cootamundra

Lateral flow and accumulation on flats along streamline



Regional salinity mapping from radiometrics.

Subset area approx. 20km wide

Lateral flow and accumulation in a major fault line

Accumulation at break of slope (circular feature around hill)

Salinity Pathway (fault line)

Insitu Development of Soil Salinity

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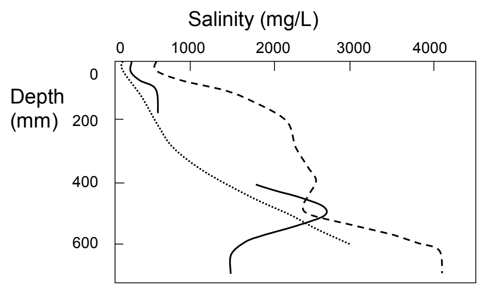
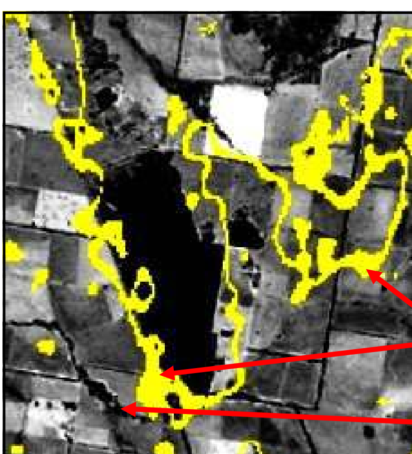




Salinity

Temora

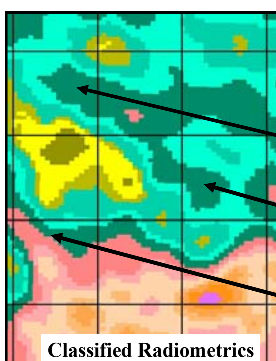
Surficial pathways mapped from radiometrics

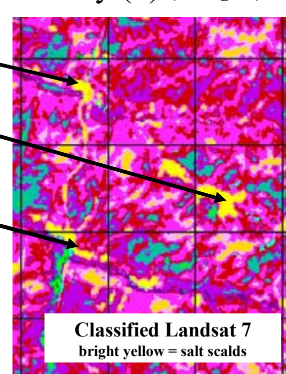
Natural surficial drainage altered by the construction of the road

Surficial salt accumulation

Natural extension of drainage line

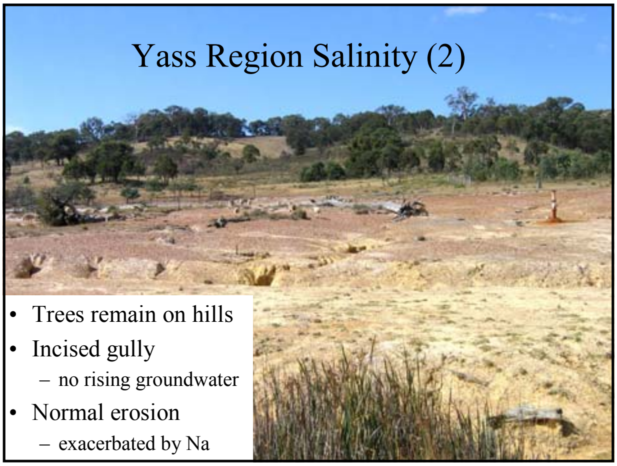
Yass Region Salinity (1) **(1km grid)**





Salinity is associated with geological unconformities

Yass Region Salinity (2)



- Trees remain on hills
- Incised gully
  - no rising groundwater
- Normal erosion
  - exacerbated by Na

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