Impact of biochar application on soil properties

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Presentation outline

- Aims and objective – section
- Soil physics
- Soil chemistry
- Soil biology
- Feedstock
- Feasibility study – based on soil fertility
- Conclusions

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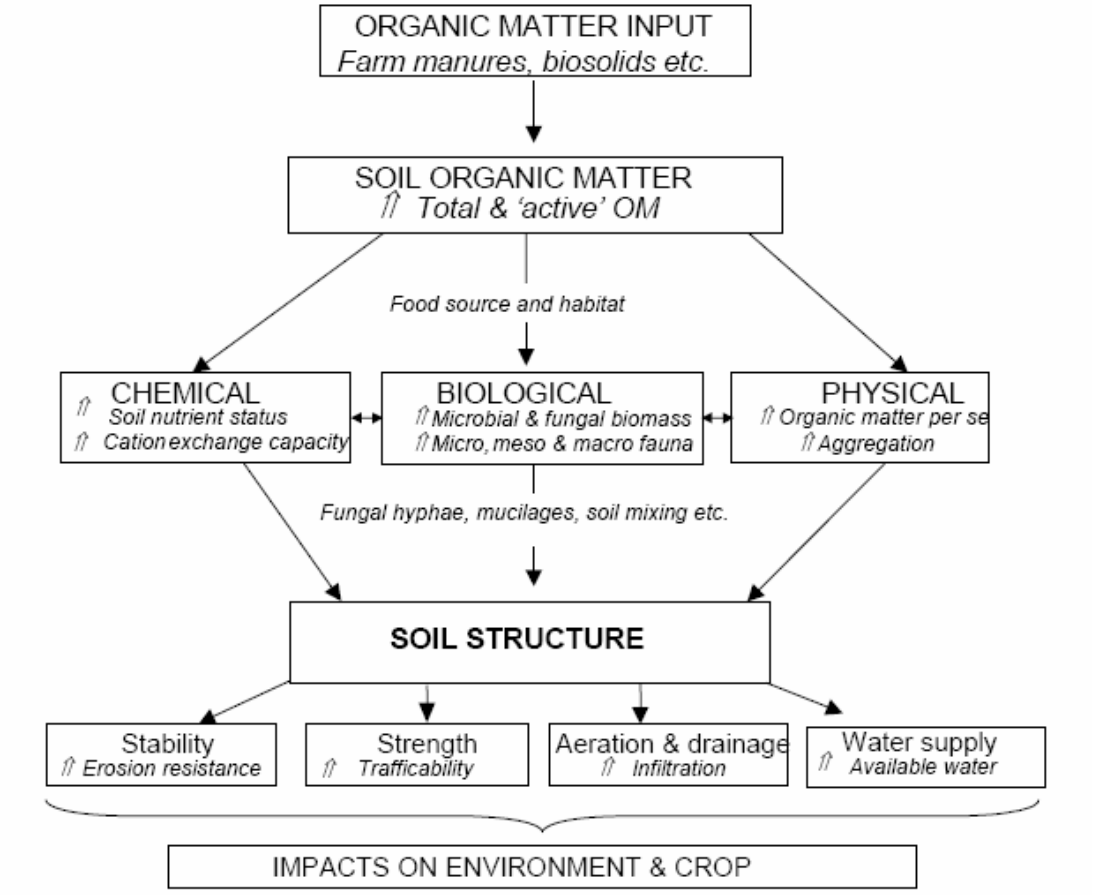
Aim :

To explore feasibility of amending soil with biochar and its impact on soil properties

Objective :

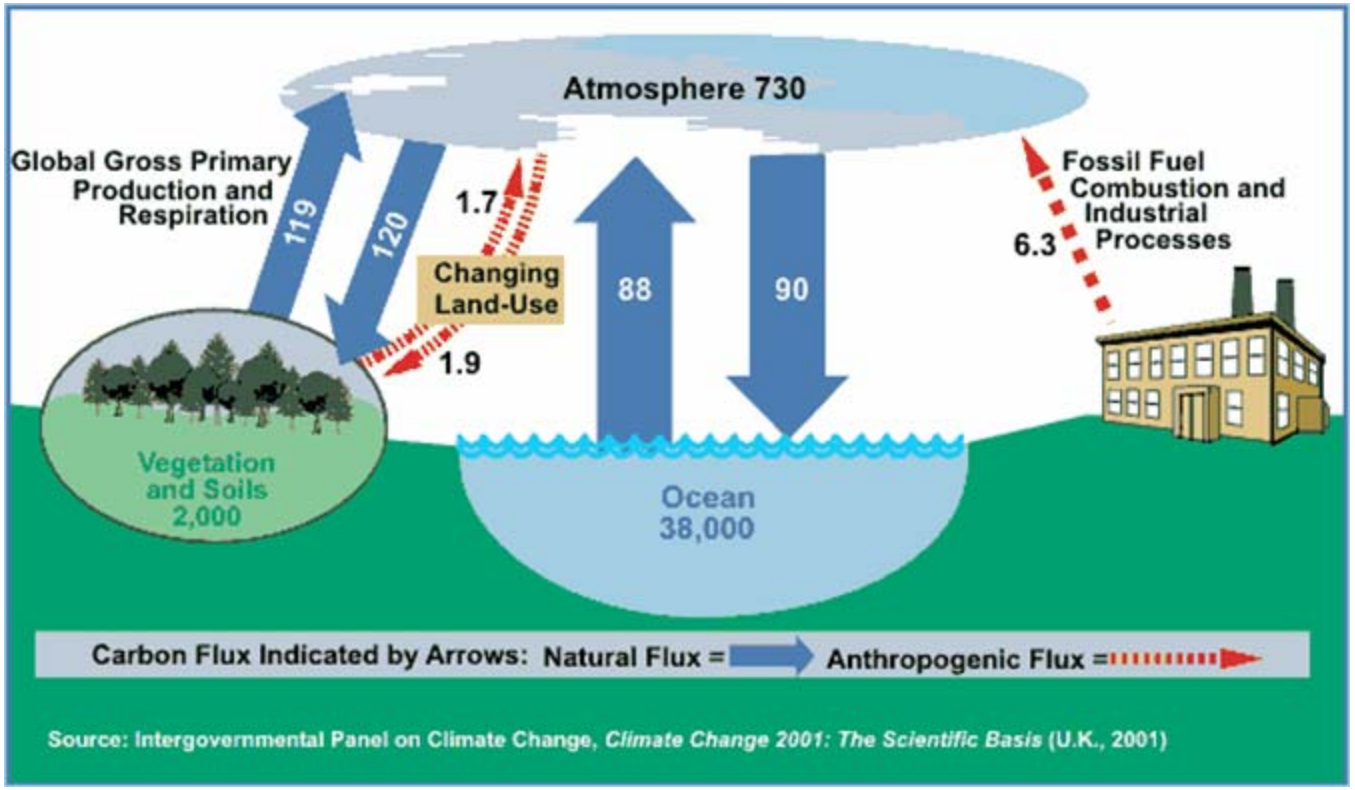
To determine the influence of biochar addition to soil on its physical, chemical and biological properties

Conceptual framework



Adapted from Sustainable Organic Resources Partnership (SORP) Technical Briefing Note 1

Carbon cycle



Units in GtC

Soil physics

- Biochar effects on :
  - Soil structure
  - Soil aggregate stability
  - Soil water

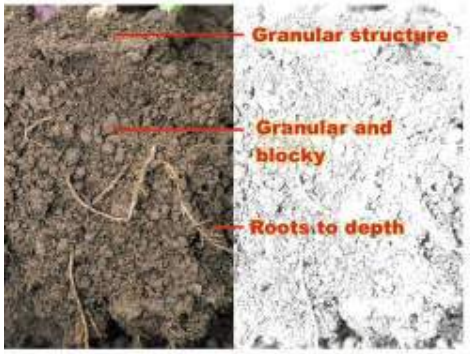
Soil physics – soil structure

- ↑soil structure or soil aeration in fine- textured soils
- biochar has a very porous nature and improve soil aggregation

Good structure

Poor structure

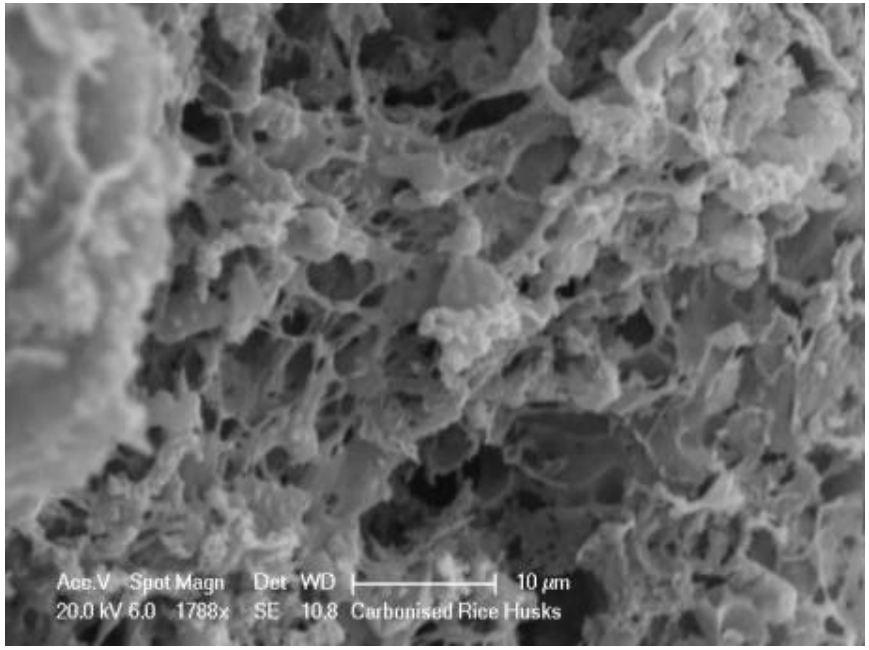
Crewe Soil Series
(Clay soil)
stoneless clay
slowly permeable
prominently mottled



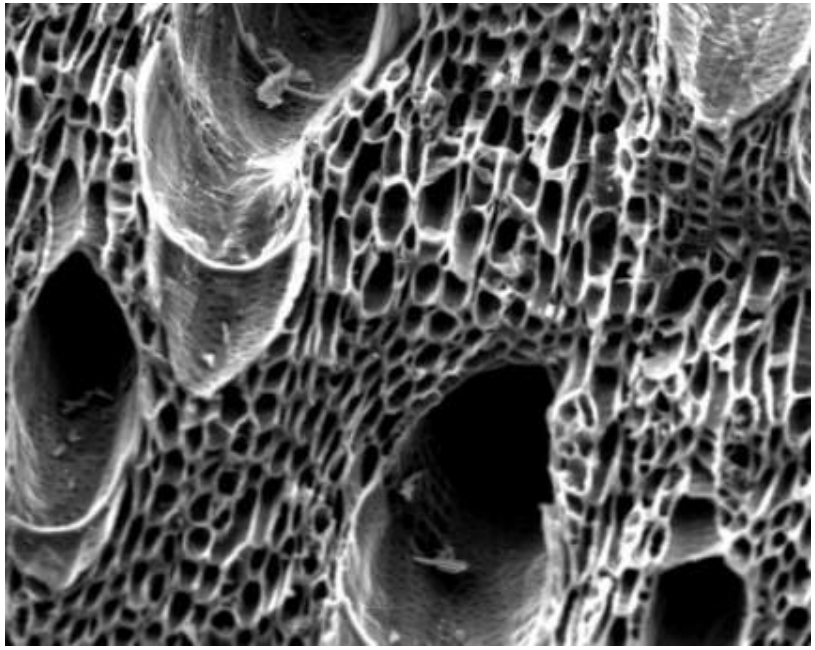
Salwick Soil Series
(Sandy Clay Loam)
slightly stony sandy clay loam
moderately permeable
more clayey with depth

Arrow Soil Series
(Sandy Loam)
very slightly stony
sandy loam
deep permeable
loamy sand at 80cm depth

SEM of biochar

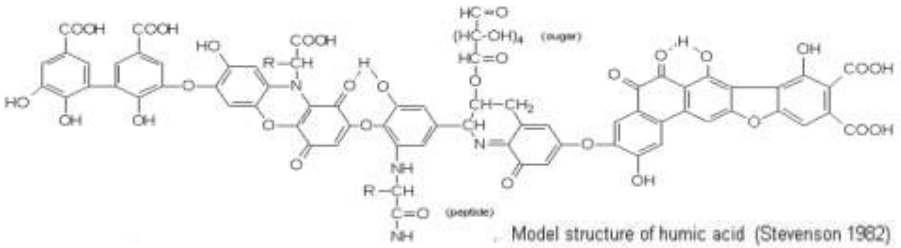


Courtesy of UK Biochar Research Centre



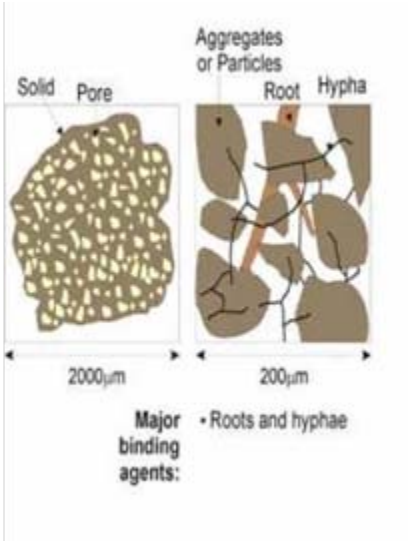
Courtesy of www.carboncommentary.com

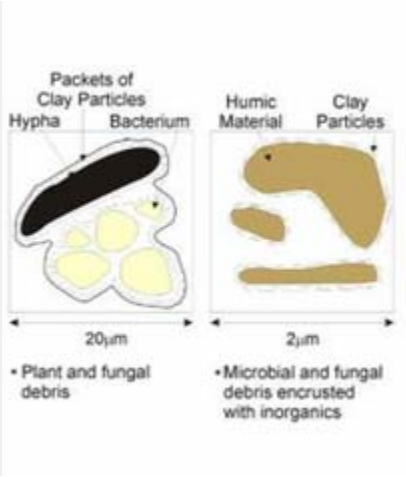
Soil physics – aggregate stability

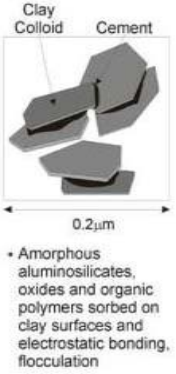


Model structure of humic acid (Stevenson 1982)

- ↓ the entry of water into the aggregate pores leading to an ↑ in aggregate stability
- hydrophobic polyaromatic backbone ↓ the entry of water into the aggregate pores leading to an increased aggregate stability and water availability



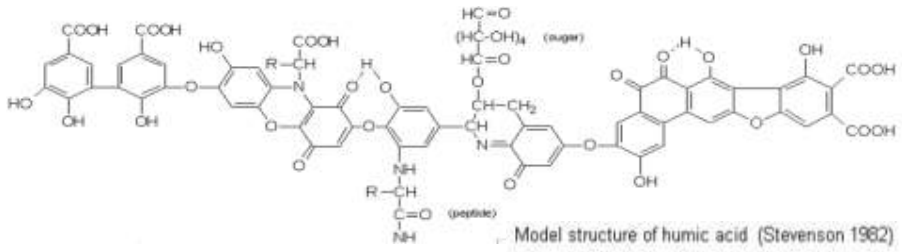




http://www.landfood.ubc.ca/soil200/interaction/structure.htm

Soil physics – soil water

- ↑ water retention in Amazonian charcoal rich soils
- formation of organo-mineral complexes by functional groups of the humic acids
- increased aggregate stability – holds water
- ↑ moisture in sandy soils – mechanisms ?



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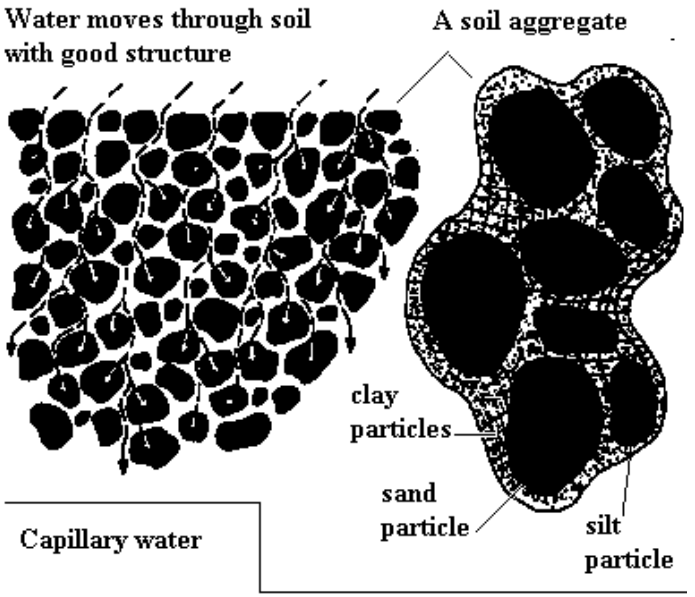


www.uq.edu.au/

Soil physics – research questions

soil workability

physical characteristics of biochar on soil processes - mechanisms

soil hydrophobicity

biochar application influence soil aggregate stability – link to rates

mechanisation and application

physical properties of biochar change over time

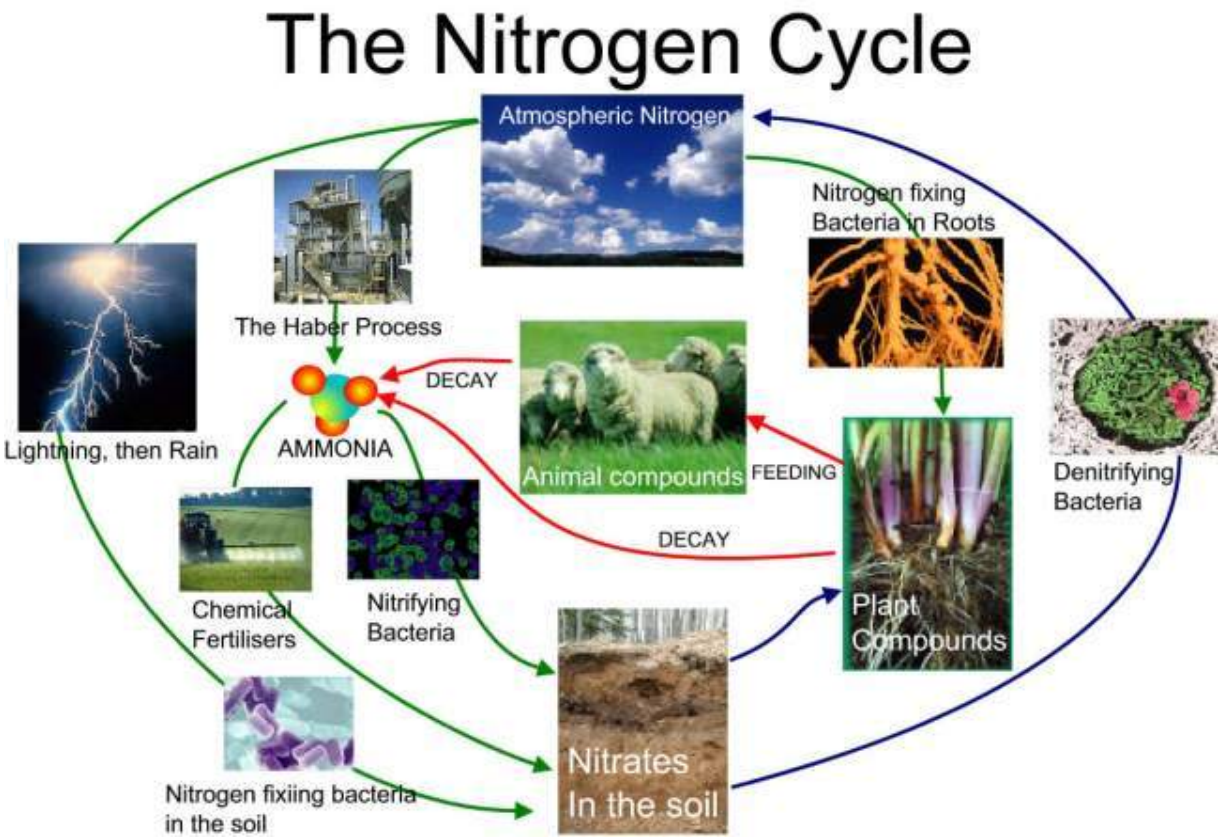
Soil chemistry

- Biochar effects on :

  - soil greenhouse gas emissions

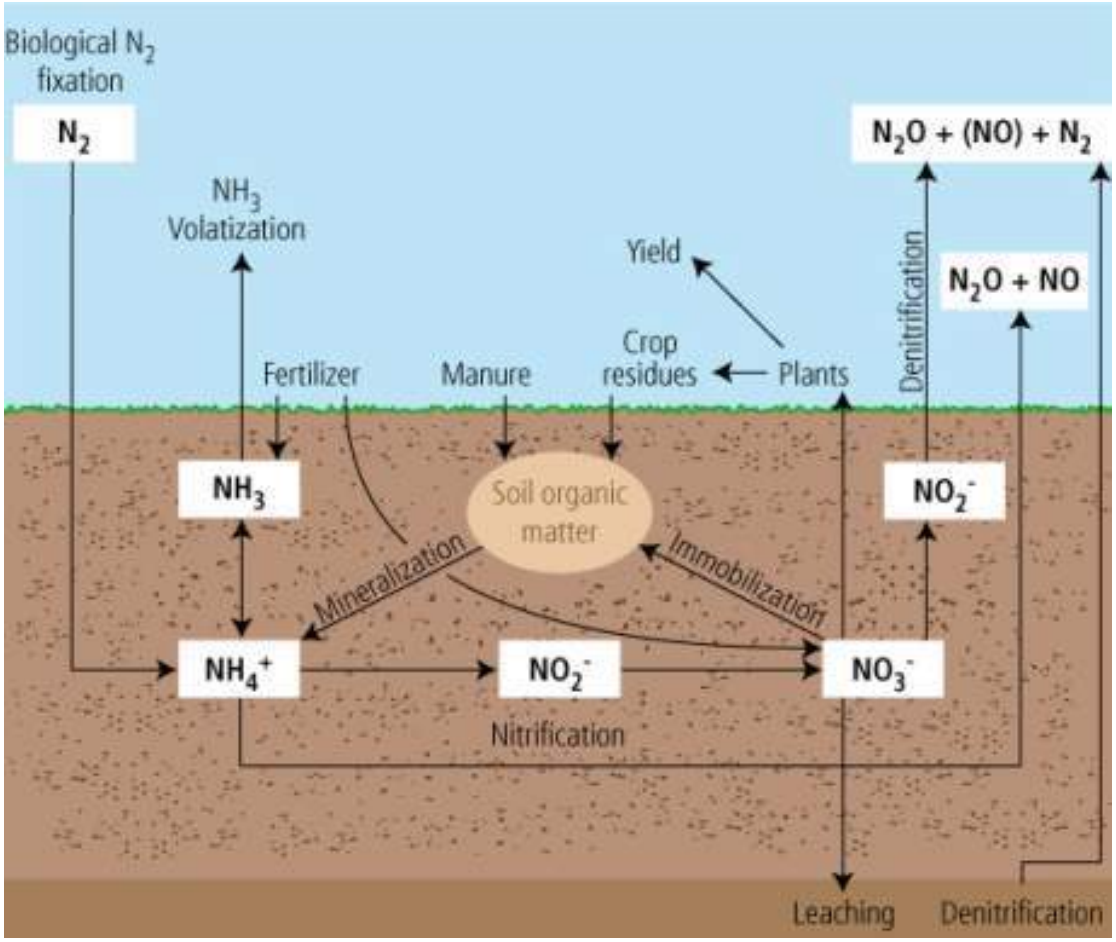
  - nutrient dynamics – diffuse pollution (linked to CEC)

Nitrogen cycle - basics



http://www.hextable.kent.sch.uk/content/departments/science/sciencegr/resources/quizzes/GCSE%20Modular%20Science%20-%20Environment_files/Nitrogen%20Cycle.jpg

Soil N dynamics



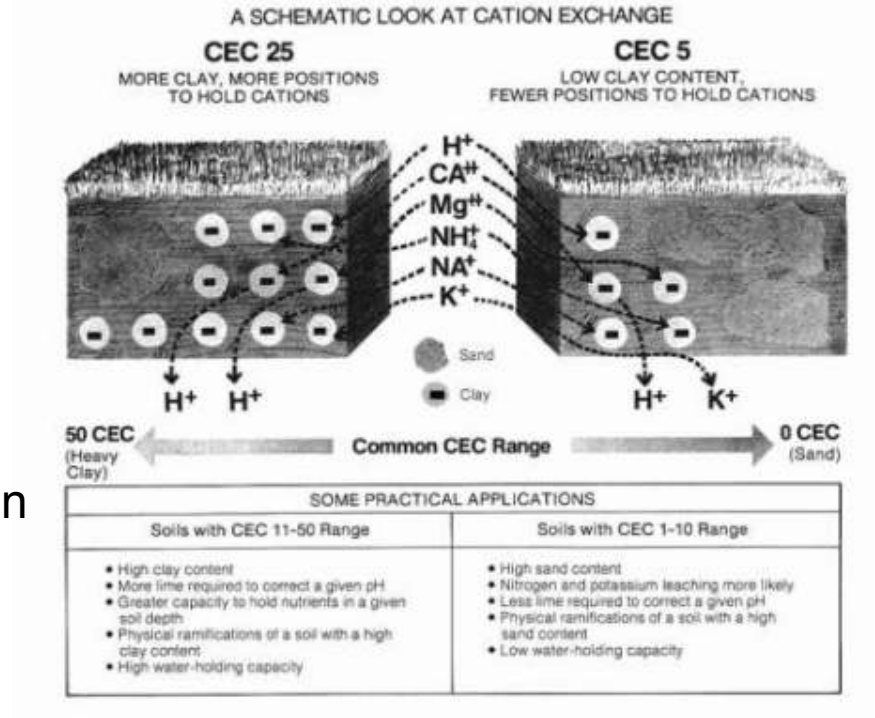
http://www.fertilizer.org/var/ifa/storage/images/media/images/images-sustainability/climate-change/html6/236413-1-eng-GB/Soil-nitrogen-cycle.jpg

Biochar and GHG

- N_2O and CH_4 - 4% and 3% respectively from UK agriculture
- The major controlling factors for N_2O production are the amounts of NH_4^+, NO_3^-, water (oxygen), SOM, texture and temperature
- Biochar encourages denitrification : encouraging the activity of enzymes involved in reduction of N_2O to N_2
- Biochar – high C/N ratio, induce strong N immobilisation initially
- Liming effect by biochar – soil pH ↑, N_2O ↓
- Biochar – CEC influence on NH_4^+ and NO_3^- (precursors to N_2O formation)
- Mechanisms – not fully understood

Cation Exchange Capacity (CEC)

- biochar – ↑ surface area, negative surface charge & charge density
- retains nutrients – link to crop uptake & diffuse pollution (associated to NVZs)
- better nutrient uptake by crop, ↓ reliance on manufactured fertilisers
- adsorbs phosphate – mechanism ?



http://www.spectrumanalytic.com/support/library/ff/CEC_BpH_and_percent_sat.htm

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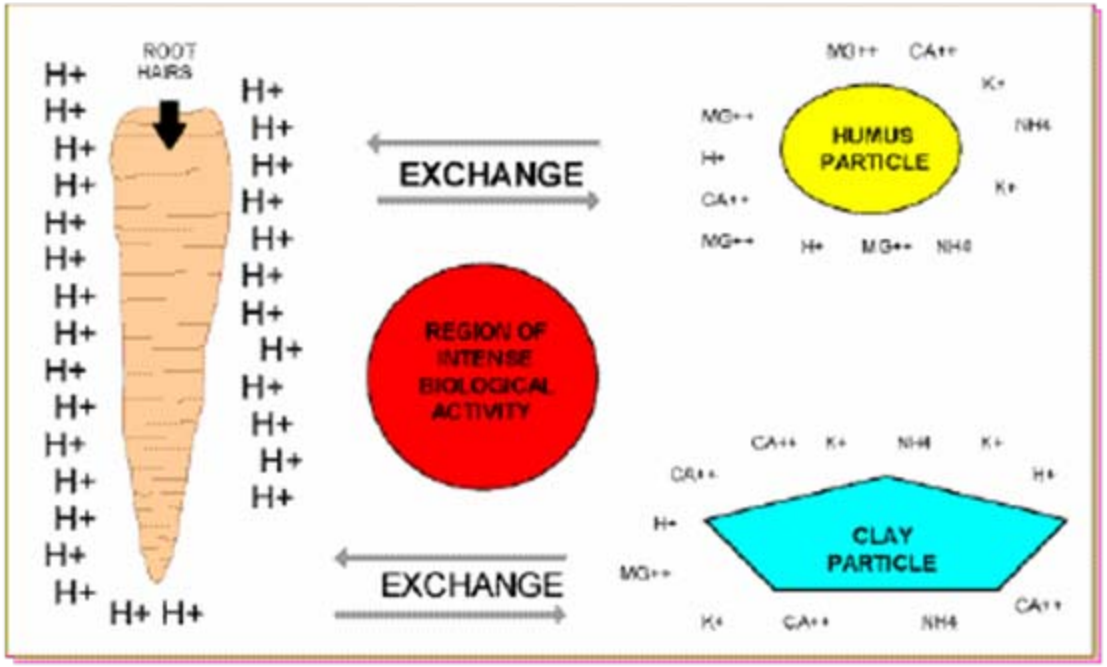

http://www.microsoil.com/CEC.htm

Erosion – diffuse pollution

Soil nutrient dynamics

- biochar has very high C/N ratios (7 – 400 ; mean = 61)
- Compost with C/N ratio > 25 – 30 : immobilises inorganic N
- But biochar with high C/N ratio, mineralises N, greater availability (??)
- Data on available nutrient from biochar is limited ($N_{available}$ = low, $P_{available}$ = variable, $K_{available}$ = high) – depends on feedstock and production condition (Temperature)

Diffuse pollution

- Evidence to date suggests that biochar application to soil will affect nutrient leaching through several mechanisms,

  - increasing the retention of water in the rooting zone, by directly binding or sorbing nutrients or

  - by interacting with other soil constituents, and by facilitating the movement of attached nutrients when fine biochar particles are transported in percolating water

Soil chemistry – research questions

dynamics of N_2O emission from soils applied with biochar – (field vs. laboratory scale) – mechanisms

Nutrient availability and biochar – C/N ratios – mechanisms

CEC and nutrient (nitrate and phosphate) retention

Diffuse pollution + biochar – mechanisms (NVZs)

Catalyst - mineralisation of nutrients from compost, sewage sludge

Soil biology

- Biochar effects on :

  - soil fungal diversity

  - soil microbial population

Soil biology – fungal diversity

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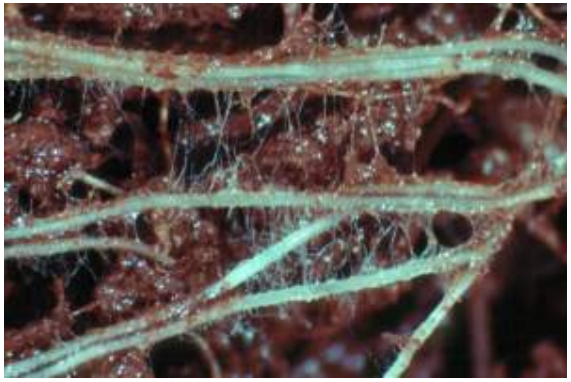
- Biochar interaction with mycorrhizal fungi is the one which has been studied the most

- Mycorrhizae are common root-fungal mutualisms

- Mycorrhizae colonise important crops (corn, rice, wheat) – agro-ecosystem productivity and sustainability



Soil biology – microbial population

- Porous nature of biochar – adsorption sites for microbial communities (+ nutrients and protection from predators)

- Availability of nutrients – linked to enzymes secreted by microbial community

- + biochar, ↑ microbial biomass but ↓ microbial activity

  (biochar amendments ↑ the population of microbes but the rate of degradation of the substrates that are used by the microbes is slower indicating the potential stability and long-term persistence of biochar in soil)

Soil biology – research questions

Fungi influence on altering soil physiochemical properties

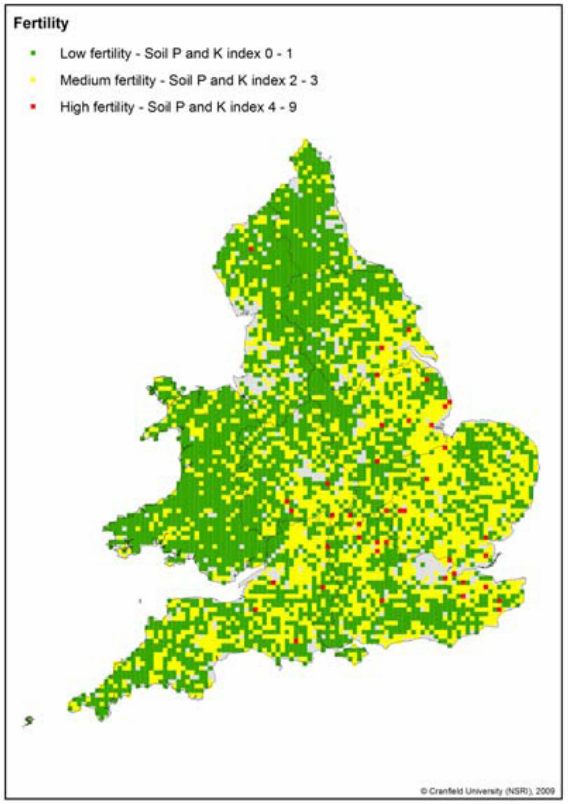
Biochar-colonising microorganisms – mechanisms

Indirect effects on mycorrhizae through effects on other soil microbes?

Bacteria vs. fungi competition when colonising biochar surfaces

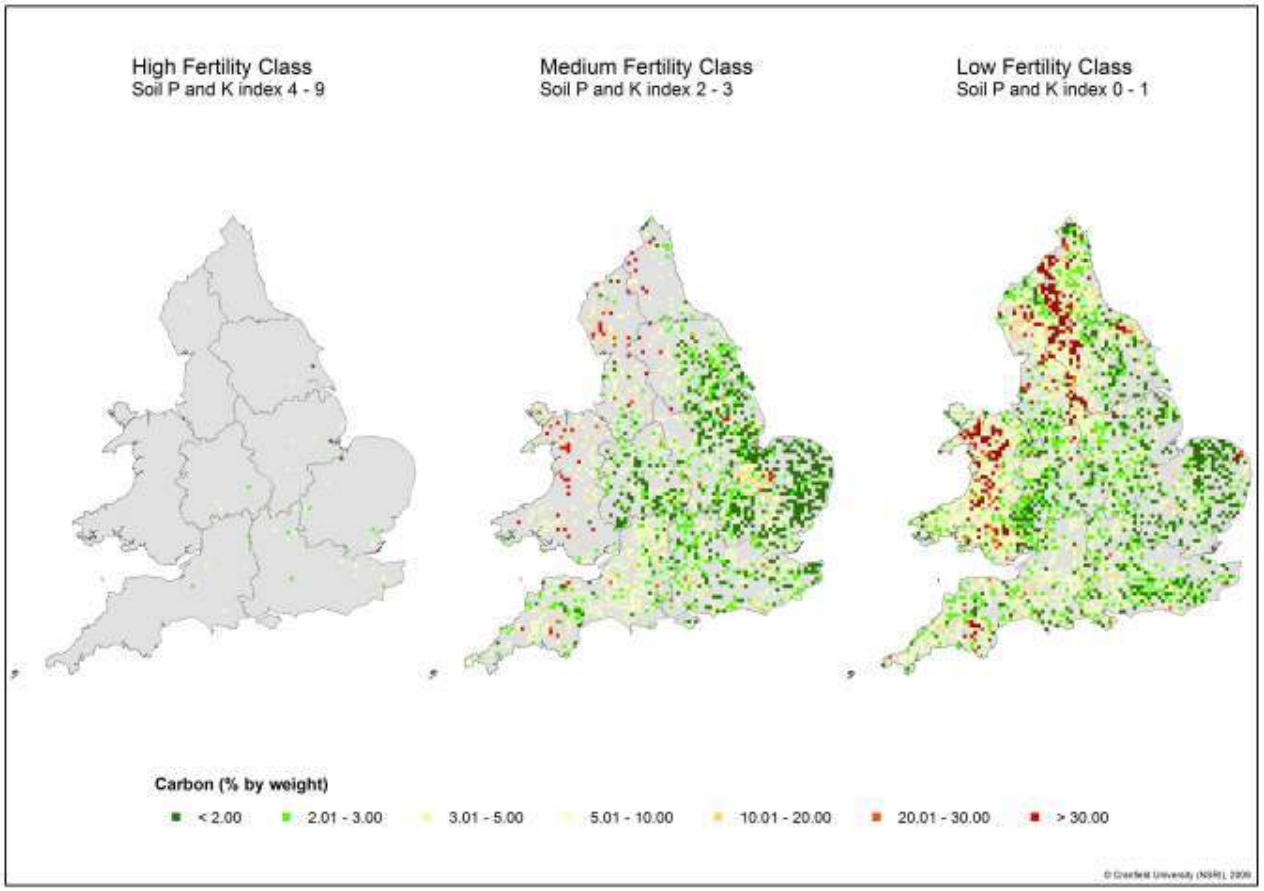
Soil fertility

Spatial soil information showing soil fertility in England and Wales based on P and K indexes



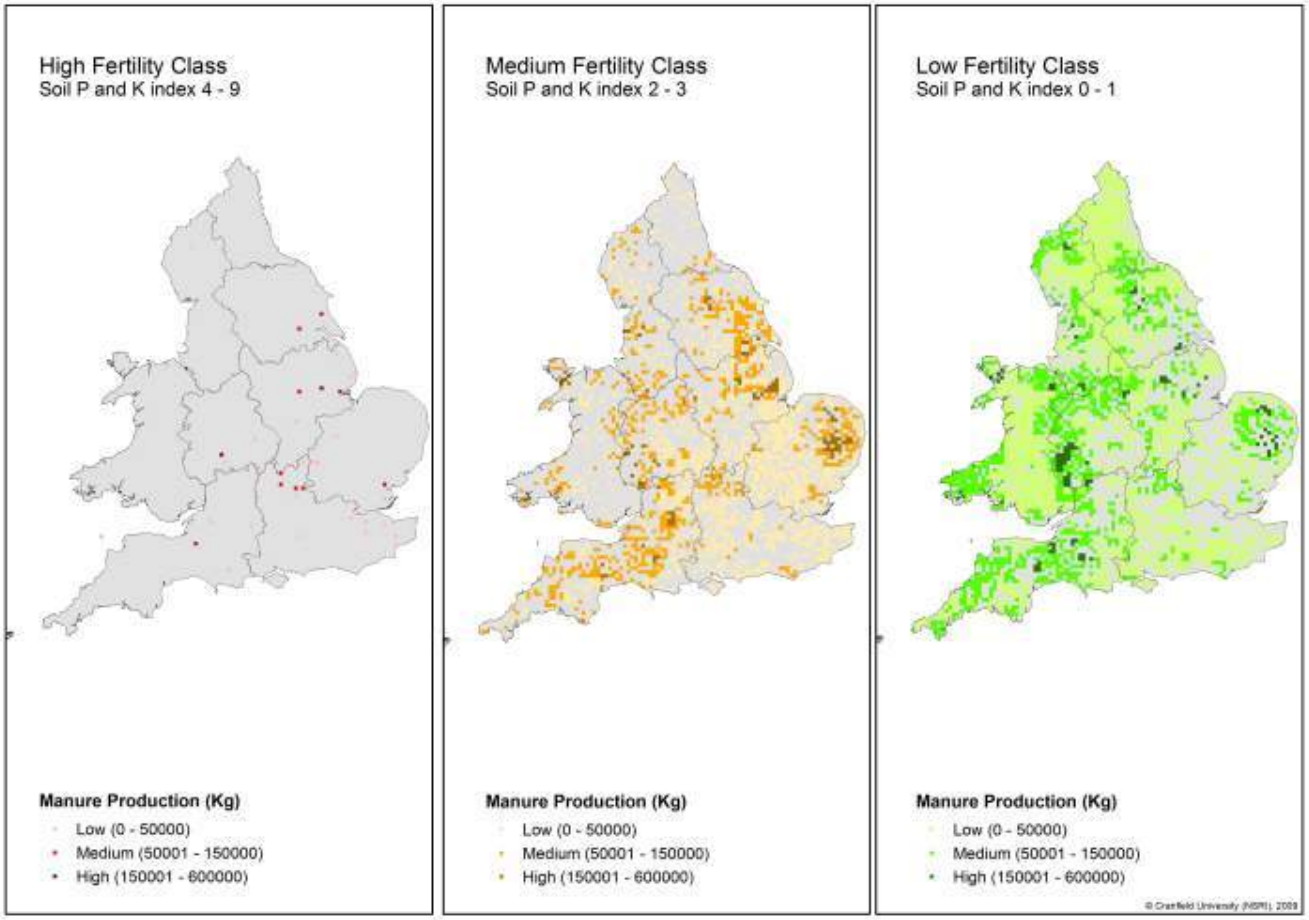
Soil carbon_soil fertility

Spatial soil information showing soil carbon (in % by weight) and corresponding soil fertility in England and Wales



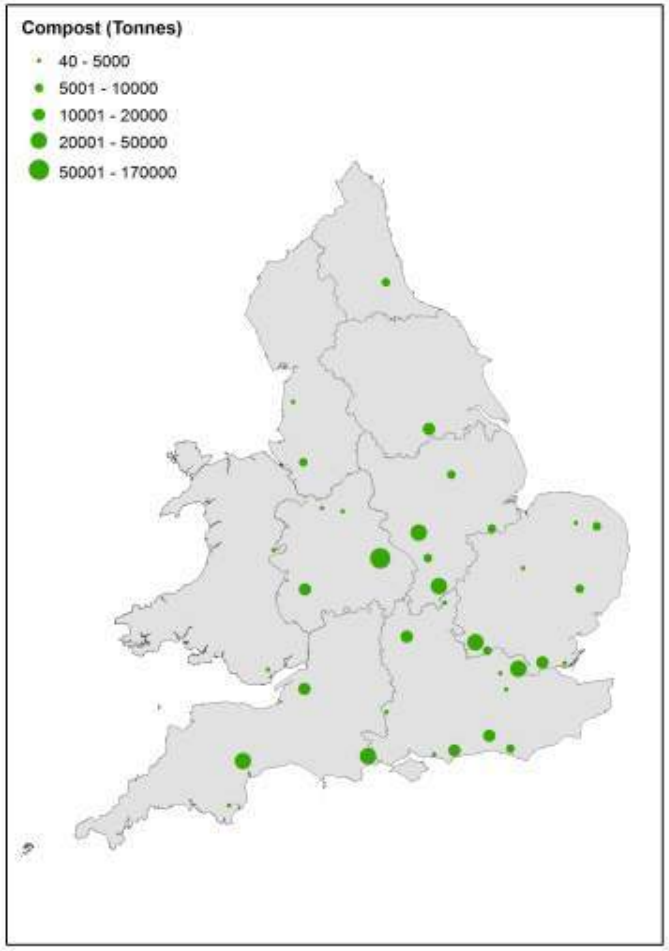
Feedstock - Manure

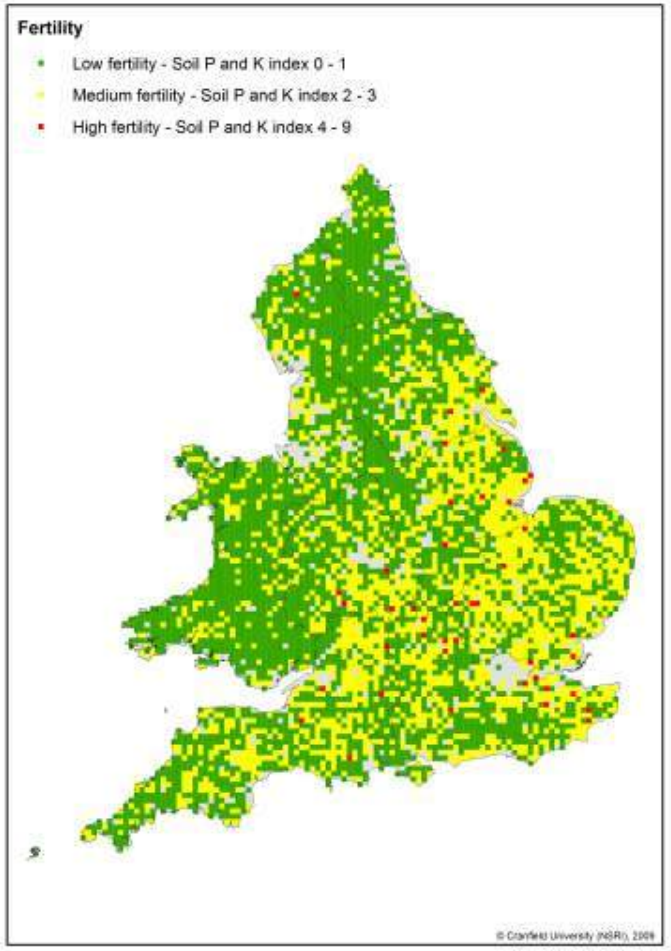
Spatial soil information showing manure arising as potential feedstock of biochar and corresponding soil fertility in England and Wales



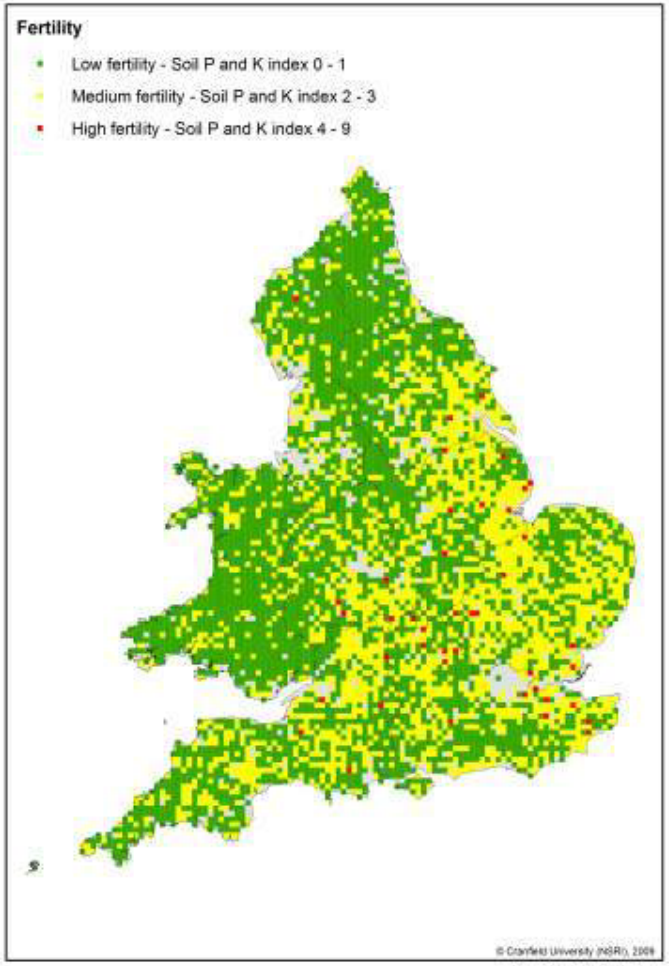
Feedstock - Compost

Spatial soil information showing compost arising as potential feedstock of biochar and corresponding soil fertility in England and Wales

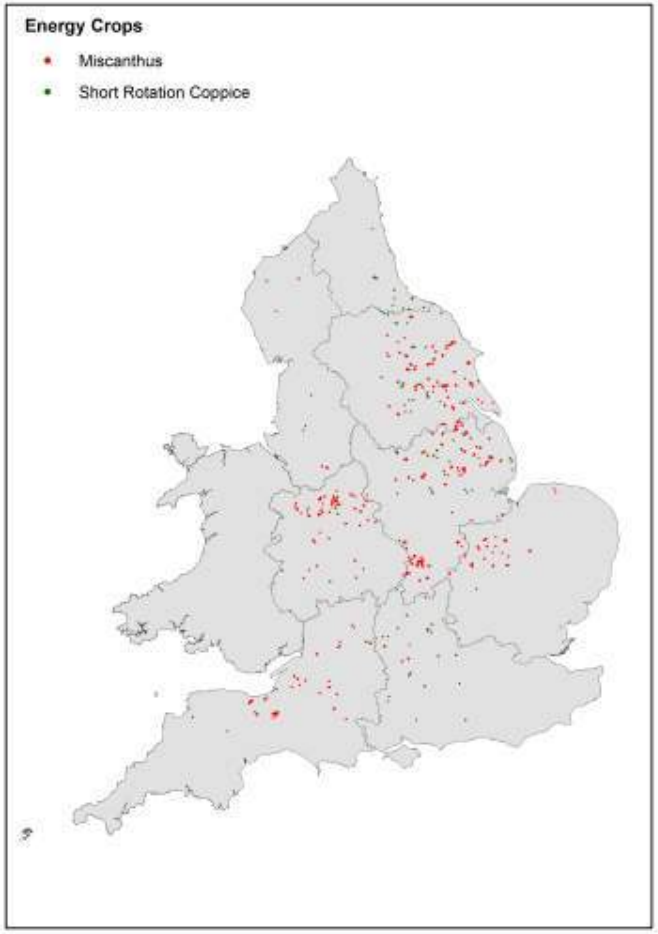




Feedstock - Sludge (East Anglia)



Feedstock – Bioenergy crops



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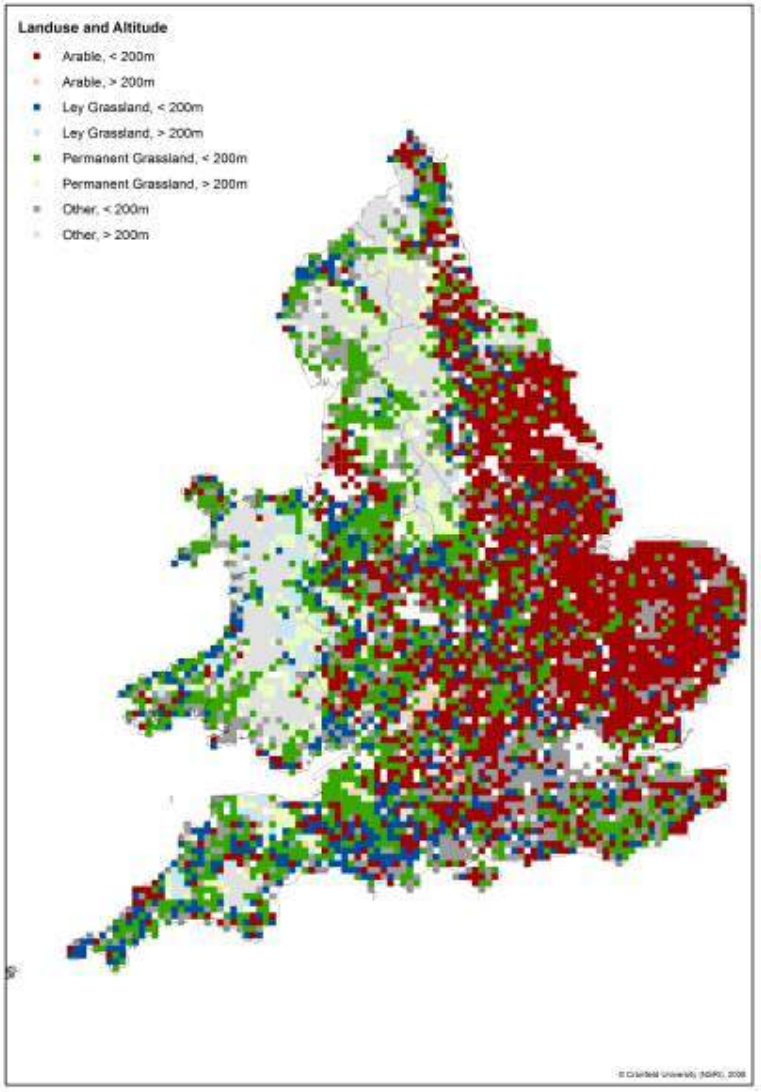
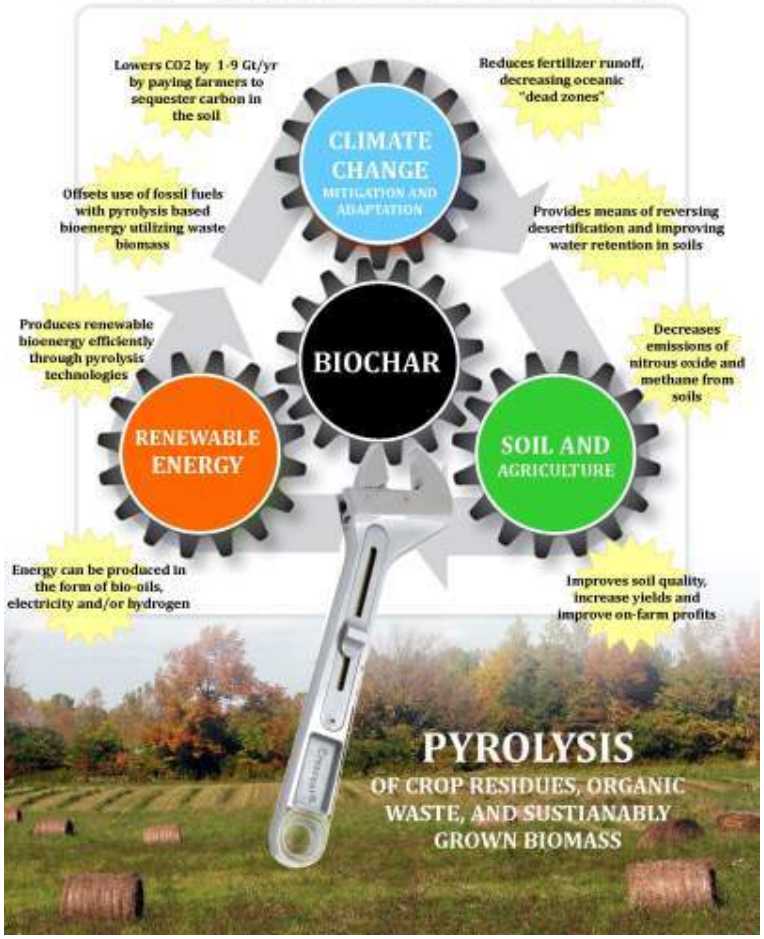


Policy drivers

- National level
  - DEFRA
    - Nitrate Vulnerable Zones
    - Soil Action Plan
- European Union Level
  - 'Towards a Thematic Strategy for Soil Protection'
  - 6th Environmental Action Programme
  - Water Framework Directive
    - Eroded soil / sediment reduces water quality
  - Soil Framework Directive (forthcoming)

SCHEMATIC OF BIOCHAR SOLUTIONS



Courtesy of Biochar Farming

Conclusions

Influence of biochar on soil properties

Soil structure	↑
Soil water	↑ ?
Soil aggregate stability	↑
Soil GHG	↓ ?
Soil nutrient dynamics	↑ ?
Soil fungal diversity	↑
Soil microbial population	↑ ?

Conclusions

- Biochar addition influences soil physical, chemical and biological conditions in may ways
- Initial work shows best influence of biochar on light soils
- There needs to be more research done to understand the mechanisms involved in the biochar-soil interactions
- Regions with some low fertility soils can be used as sites for initial work on biochar application on a field scale