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Renewable Energy

THE GREEN HOUSE

BIOCHAR – SUSTAINABLE AGRICULTURAL

THE BENEFITS OF BIOCHAR IN SOIL

There are many benefits of biochar application in agricultural systems as a soil conditioner and to increase crop productivity[1,2]. This brief guide provides an overview of the outcomes from biochar application that have been seen by farmers across the world.

EFFECTS ON SOIL PHYSICAL PROPERTIES:

The physical properties of soil relate to the soil texture and structure. These properties control how air, water and dissolved nutrients move through the soil and impact how plants grow.

Figure 1: Benefits of biochar[3]

- Bulk density and soil compaction: Bulk density is a measure of how compacted the soil is and is the mass of soil contained in each cubic meter of ground. Compacted soils impact root development and slow the rate at which water can enter the soil, resulting in greater runoff and loss of water and nutrients[4]. Biochar addition can decrease soil bulk density by between 3 and 42%, reduce compaction by over 10% and improve porosity (the space between soil particles) by between 14 and 64%[5–7].
- Water holding capacity: Water holding capacity is a measure of the amount of water that a soil can hold or how much water is available to plants from the soil[8]. Biochar addition can increase water holding capacity, with studies reporting an average improvement of 15%[5]. This reduces the amount of irrigation required.
- Saturated hydraulic conductivity: Saturated hydraulic conductivity is a measure of how easily water (and nutrients) can move through a soil[9]. Biochar addition can increase saturated hydraulic capacity by up to 88%, and on average by 25%.[5,7]. This also reduces irrigation requirements.

EFFECTS ON SOIL CHEMICAL PROPERTIES:

The chemical properties of soil relate to the levels and availability of nutrients needed for plants to grow. Nutrients that are essential for plant growth include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S).

- pH: Soil pH impacts the availability of nutrients from fertilizers. Most crops grow ideally between a pH of 6 and 7.5[10,11]. Biochar application reduces soil acidity due to its alkalinity and buffering capacity, pushing the soil pH values of acidic soils closer to a neutral pH of 7[5,7].
- Salinity: Salinity is a measure of the quantity of salts contained within the soil. High salinity levels, which can often occur through the use of salty groundwater for irrigation, can impact plant growth. Biochar application reduces excess salinity, as biochar adsorbs the salts, thus helping limit the effect of salt stress on crops[5,7].
- Cation exchange capacity (CEC): CEC is a measure of the soil's ability to hold cations. Many important nutrients, including potassium, phosphorous, magnesium, sodium and calcium, exist as cations within soils and therefore the CEC shows the soil's ability to retain these nutrients (i.e. prevent washout of these nutrients). The cations also prevent soil acidification, ensuring that the soil's pH remains in the right range[12]. Biochar addition can increase CEC of some soils by up to 55%, thus limiting the leaching of these important nutrients and ensuring that fertilizer requirements are minimised [5,7]. Soils with a CEC below 100 mmolc.kg-1 show the most benefit from biochar addition, with crop yields increasing by between 100 and 250%[13].
- Soil organic matter (SOM): SOM is a fraction of soil that is composed of anything that was once alive. This fraction provides nutrients for soil microbes and plants, impacts soil physical properties and influences how water is stored within the soil[14]. Biochar addition results in long-term increases in soil organic matter, as approximately 97% of the applied carbon is sequestered within the soil (10 to 100 times more stable than other sources of soil organic matter)[5].

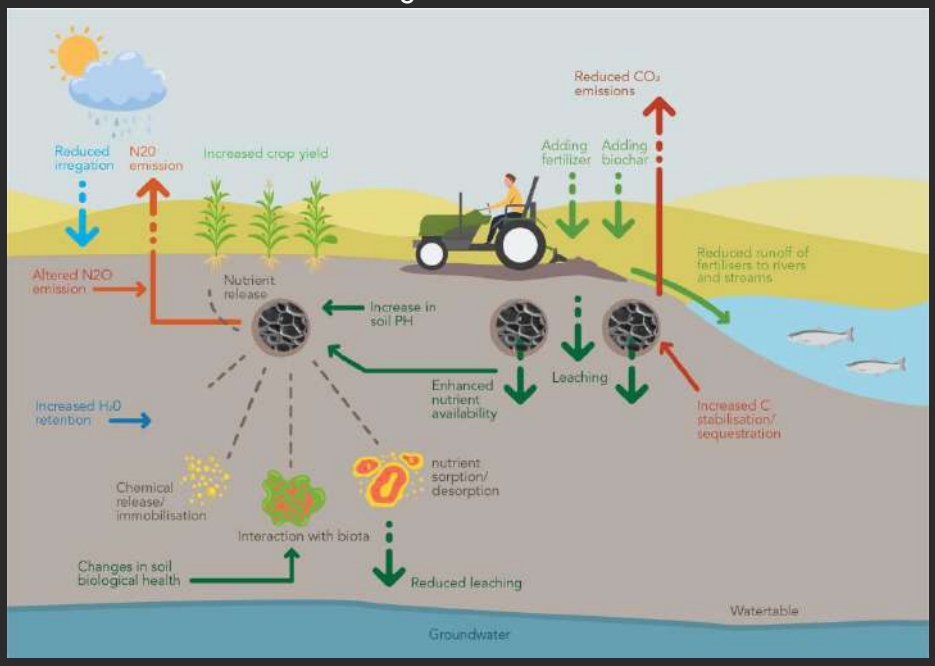

Figure 2: Benefits of biochar application to soils[17]

EFFECTS ON WATER USE AND FERTILIZER USE:

- Biochar application impacts water use on the farm in numerous ways, with impacts varying based on soil, biochar and management factors. Studies indicate average overall water use efficiency improvements of 20%, with plant water use efficiency improvements in the region of 10% for industrial & cereal crops and in excess of 40% for leafy plants (e.g. vegetables, berry bushes)[15].
- Biochar acts as a form of slow-release fertiliser[16]. Fertilisers that are applied to biochar-enriched soils remain in the soil and are not washed away. This means farmers need to apply less fertiliser [5,7,9,13].

EFFECTS ON SOIL BIOLOGICAL ACTIVITY:

Soil is extremely complex and its health influences how well plants will grow and the yield that will be possible. Microbes (bacteria, fungi, nematodes etc.) play a key role within soils, as they help to cycle nutrients, stabilise the soil, improve water holding capacity and improve water quality. Most microbes also help plant health by keeping pest levels low and releasing beneficial compounds into plant roots and soils[18]. A simplified explanation of microbe's role within the plant food web shown below.

Biochar provides carbon and other nutrients for soil microbial communities, as well as offering a suitable habitat for growth. Together these factors result in increased microbial activity and microbial biomass within soils[6,13,19], with studies showing an average 25% increase in microbial biomass carbon and 22% increase in microbial biomass nitrogen[20].

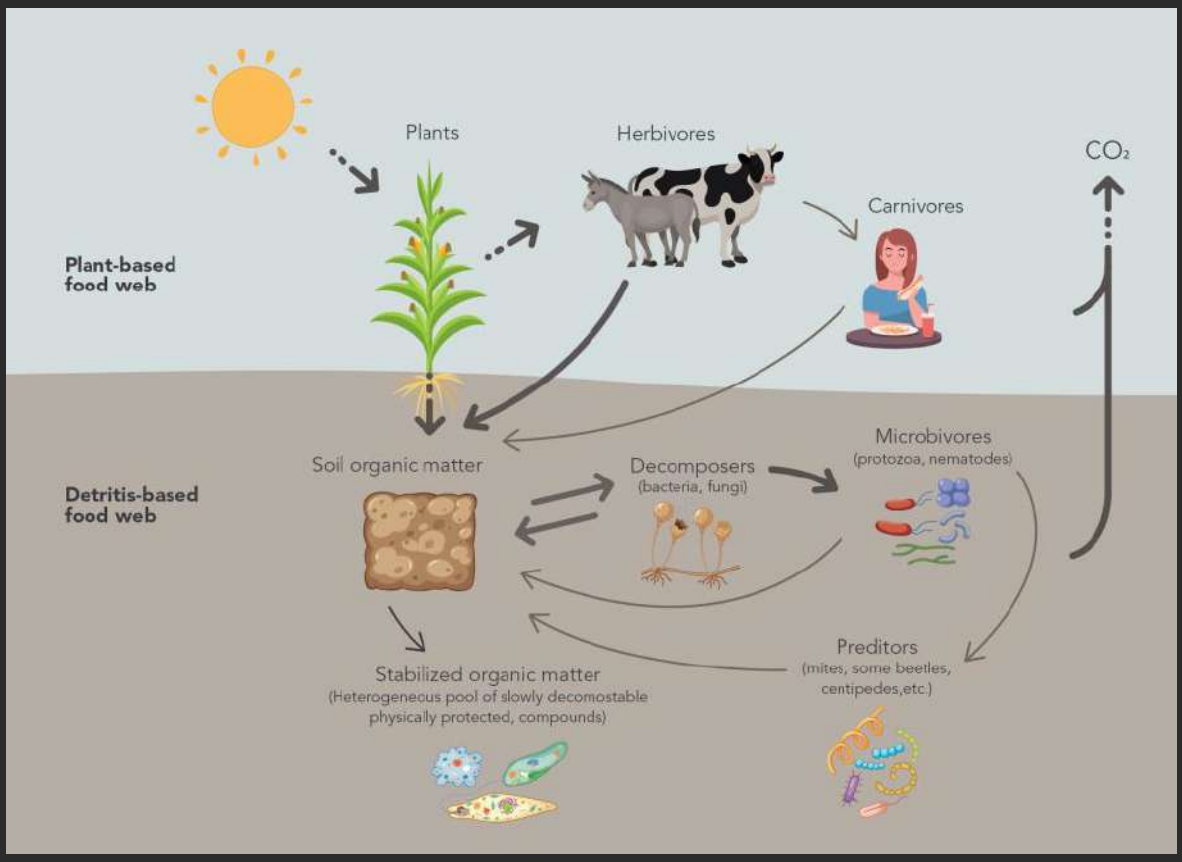

Figure 3: Microbial role within the plant food web[18]

EFFECTS ON CROP PRODUCTIVITY:

When it is added to soil, biochar has generally been shown to be beneficial for growing crops. Crop yields have been shown to increase 10[1] to 42[13] percent with biochar additions, with the greatest increases on low-nutrient soils[1,2,5]. The impact of biochar on crop yield has been extensively studied all over the world.

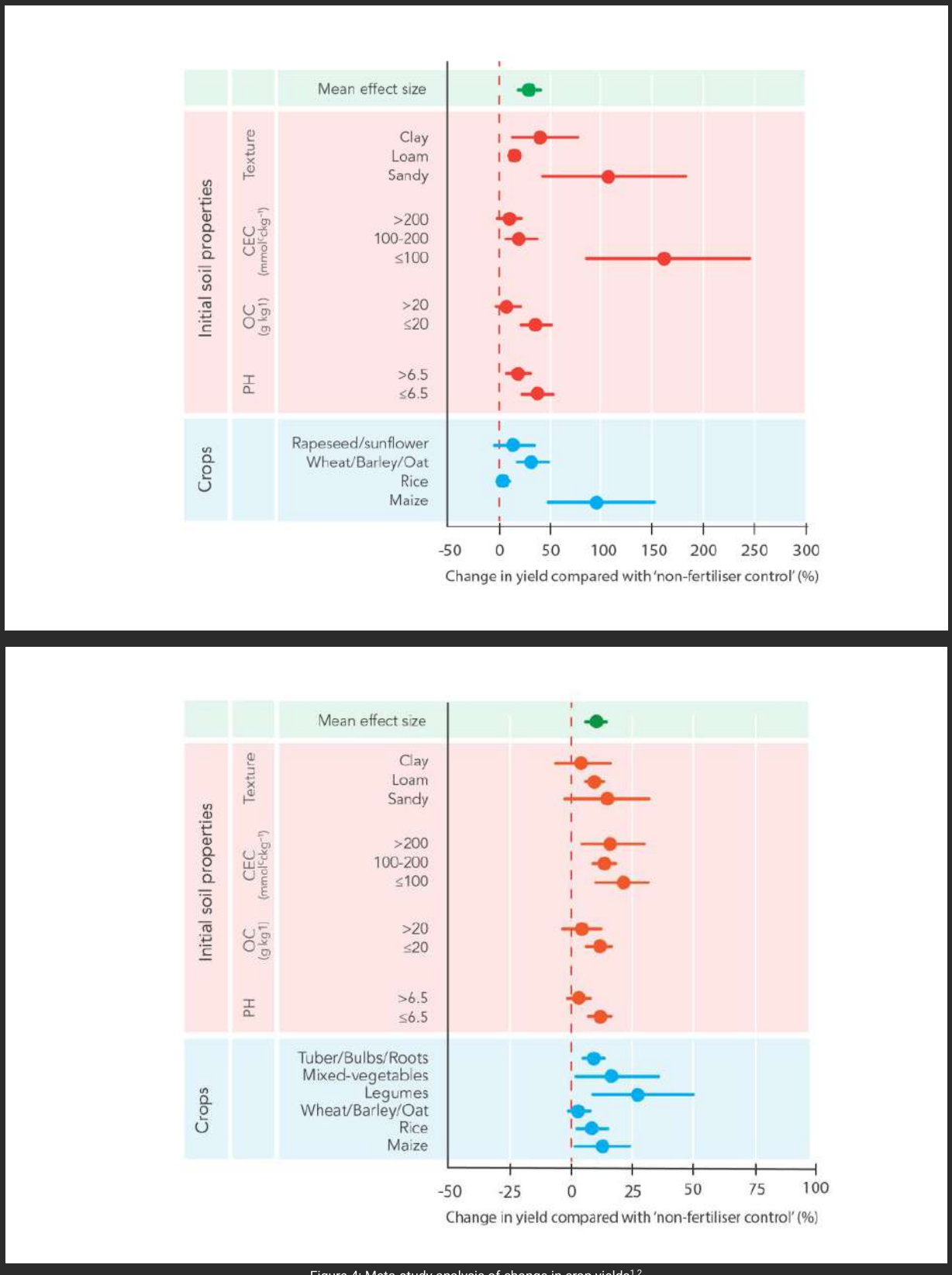

Figure 4: Meta-study analysis of change in crop yields[1,2]

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FIELD CROPS

Examples of impact of biochar addition on field crop yields:

CROP TYPE	APPLICATION QUANTITY	YIELD CHANGES	OTHER BENEFITS
MAIZE	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. MAIZE SPECIFIC STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 1.9 TONNES/HA[2].	GRAIN YIELDS IN FIELD TRIALS INCREASE BY UP TO 96% WHEN COMPARED WITH NORMAL FERTILISING[2]. AVERAGE GRAIN YIELD IMPROVEMENTS OF AROUND 10% WHEN COMPARED WITH NORMAL FERTILISING[1,2].	• INCREASES SOIL PH[21,22] • INCREASES NUTRIENT AVAILABILITY[21,22] • DECREASES SOIL BULK DENSITY[22] • IMPROVES MICROBIAL ACTIVITY IN SOILS AND ROOTS[22] • REDUCES DROP IN TRANSPIRATION RATE (WATER LOSS THROUGH LEAVES) DURING DRY SPELLS[23] • IMPROVES DROUGHT TOLERANCE[22]
WHEAT	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. WHEAT SPECIFIC STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 0.2 TONNES/HA[2].	GRAIN YIELDS IN FIELD TRIALS INCREASE BY UP TO 24% WHEN COMPARED WITH NORMAL FERTILISING[2]. AVERAGE GRAIN YIELD IMPROVEMENTS OF AROUND 9% WHEN COMPARED WITH NORMAL FERTILISING[1,2].	• INCREASES SOIL PH[24] • INCREASES SOIL NUTRIENT CONTENT[22,24] • DECREASES SOIL BULK DENSITY[22] • IMPROVES MICROBIAL ACTIVITY IN SOILS AND ROOTS[22] • IMPROVES DROUGHT TOLERANCE[22]
OTHER GRAINS	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. OTHER GRAIN (NON-MAIZE, RICE OR WHEAT) STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 2 TONNES/HA[2].	GRAIN YIELDS IN FIELD TRIALS INCREASE BY UP TO 31% WHEN COMPARED WITH NORMAL FERTILISING[2]. AVERAGE GRAIN YIELD IMPROVEMENTS OF BETWEEN 3% AND 11% WHEN COMPARED WITH NORMAL FERTILISING[1,2].	

HOW TO APPLY BIOCHAR TO FIELD AND HORTICULTURAL CROPS

In fields, biochar combined with animal manure or other composts can be more effective at improving crop production than biochar alone. Biochar can also be mixed with mineral fertilizer.

Broadcast application of biochar can be undertaken. Alternatively, it can be tilled into agricultural fields or only applied to highly compacted or contaminated/degraded soils. Good results have also been shown with biochar addition directly into planting holes.

For long-term crops (e.g. vineyards), biochar can be applied directly around the base of plants or into holes/trenches dug close to plants.

Biochar doesn't need to be applied every year, as the soil condition improves over time as the biochar ages.

HORTICULTURAL CROPS

Examples of impact of biochar addition on horticultural crop yields:

CROP TYPE	APPLICATION QUANTITY	YIELD CHANGES	OTHER BENEFITS
LEGUMES	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. NON-GRAIN STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 1.6 TONNES/HA[2].	AVERAGE YIELD IMPROVEMENTS OF AROUND 27% WHEN COMPARED WITH NORMAL FERTILISING[1].	• INCREASES TOLERANCE TO DROUGHT STRESS[22]. • IMPROVES PLANT WATER AVAILABILITY[22].
VEGETABLES	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. NON-GRAIN STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 1.6 TONNES/HA[2].	AVERAGE YIELD IMPROVEMENTS OF AROUND 16% WHEN COMPARED WITH NORMAL FERTILISING[1].	• DECREASES INCIDENCES OF DISEASE[19,25]. • REDUCES WATER CONSUMPTION OF UP TO 80%[26].
TOMATOES	BIOCHAR WAS MIXED WITH POTTING SOIL AT QUANTITIES OF 1-3 WT%[19].	PLANT GROWTH INCREASED BY BETWEEN 15-20%[19].	• HALVED DISEASE MORTALITY RATE[19].
VINEYARDS	BIOCHAR APPLIED AT 25 TONNES/HA[27].	VINEYARD YIELD INCREASED BY UP TO 29% AFTER THE SECOND SEASON[27].	• INCREASES SOIL ORGANIC MATTER CONTENT[27].
TUBERS AND BULBS	GENERALLY APPLICATION RATES OF 5-10 TONNES/HA SHOW BEST YIELD IMPROVEMENTS[1]. NON-GRAIN STUDIES HAVE CONSIDERED LOWER APPLICATION RATES OF AROUND 1.6 TONNES/HA[2].	AVERAGE YIELD IMPROVEMENTS OF AROUND 9% WHEN COMPARED WITH NORMAL FERTILISING[1].	

TREE CROPS

Studies on tree growth show that biochar application increases growth rate (rate at which trees increase in weight) by 41%, with greatest growth improvements achieved during the early growth stages[20]. Australian field trials showed biochar application resulted in 20-gram heavier apples, with no reduction in firmness or sugar content[28], while trials in avocado orchards showed improved tree growth rates of up to 26% and fruit counts of up to 96%[29].

HOW TO APPLY BIOCHAR TO TREE CROPS

As with field crops, biochar combined with animal manure or other composts can be more effective at improving crop production than biochar alone.

Biochar may be spread around the base of established trees or into holes/trenches dug close to base of trees. During planting or transplanting, biochar can be applied directly to the planting holes.

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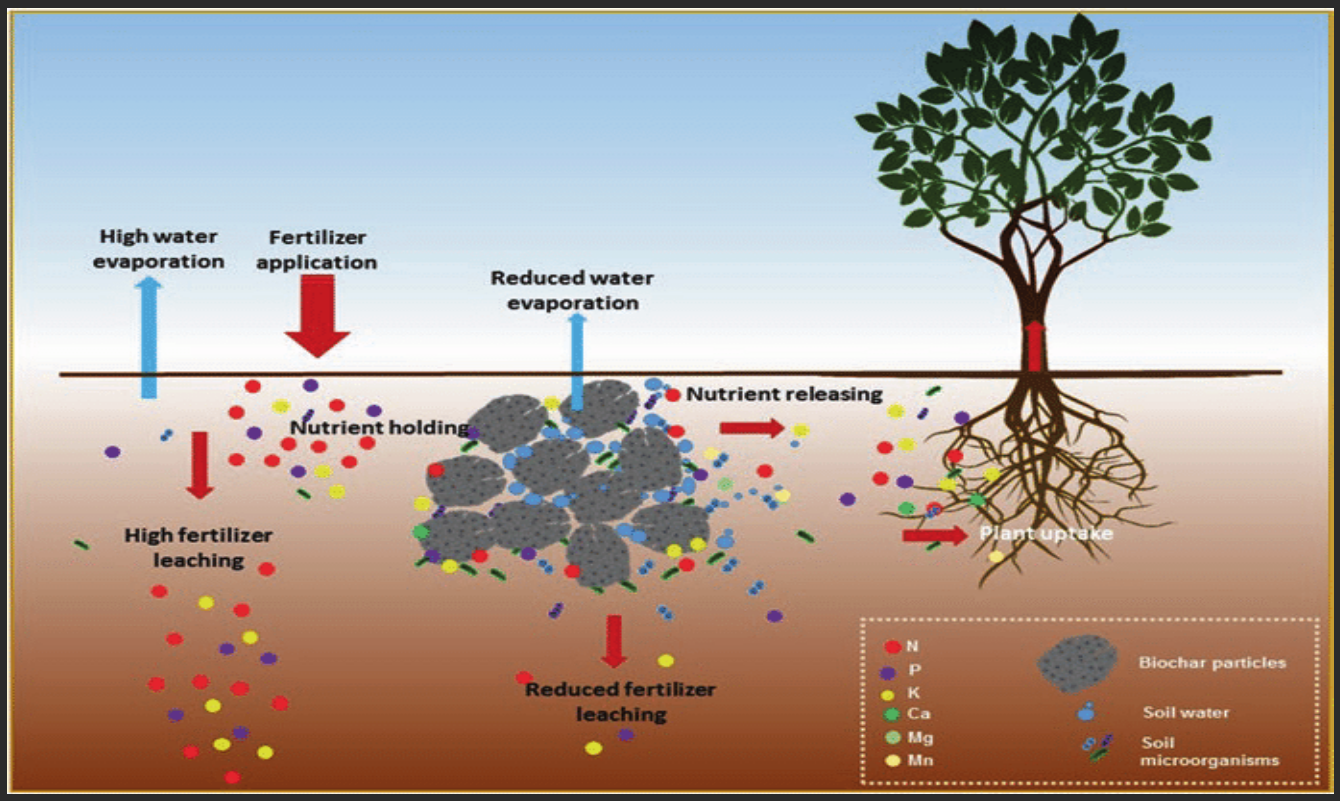
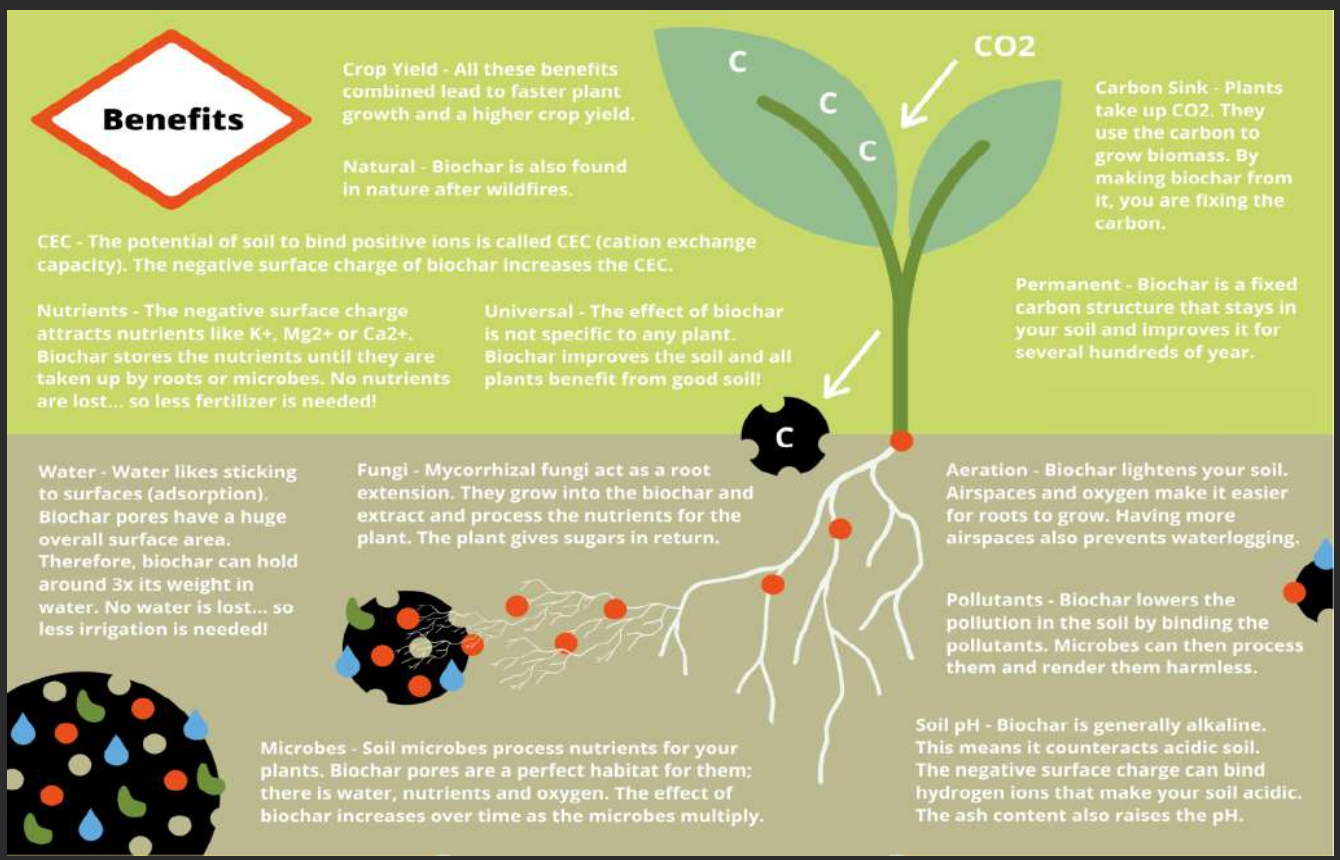
BIOCHAR ACT AS A HABITAT FOR MANY BENEFICIAL SOIL MICRO ORGANISMS



REDUCING FERTILIZER INPUT



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