The Role of Green Manures in Sustaining Soil Health and Crop Productivity in PNG – A Review

Paula Kaupa* and Rajashekhar Rao BK

Department of Agriculture

The Papua New Guinea University of Technology

DEPARTMENT OF AGRICULTURE
THE PNG UNIVERSITY OF TECHNOLOGY

SCIENCE AND TECHNOLOGY SECRETARIAT

This Presentation:

- This presentation is about what green manure crops are,
- Why Green manure crops are important in cropping systems,

- highlights the evidence for the various beneficial effects of green manures on
  - soil fertility and quality,
  - crop nutrition and yield and
  - climate-smart sustainable agriculture
- the challenges in the integration of green manure crops in PNG cropping systems.

Methodology

- A comprehensive literature search of online academic and institutional databases as well as Google Scholar and general search engines (e.g., Google) was conducted.
- The search was conducted for articles reporting the effect of green manuring on soil properties, crop yield, and Green manuring (GM) as an option for climate-smart sustainable agriculture around the globe.
- The search terms used were (“Green manure”, “in situ green manuring” “Legume green manure”) and (“Soil properties” or “soil organic matter”) and “crop yield”.
- The criteria used to include studies were:
  - studies were peer-reviewed and grey literature published in English between 2000 and 2022.
  - studies were conducted under typical field experimental conditions with modeling and laboratory incubation studies excluded
  - treatments for Green Manure were “stand-alone” and not combined with other carbon inputs such as animal manure.

What are Green Manure crops

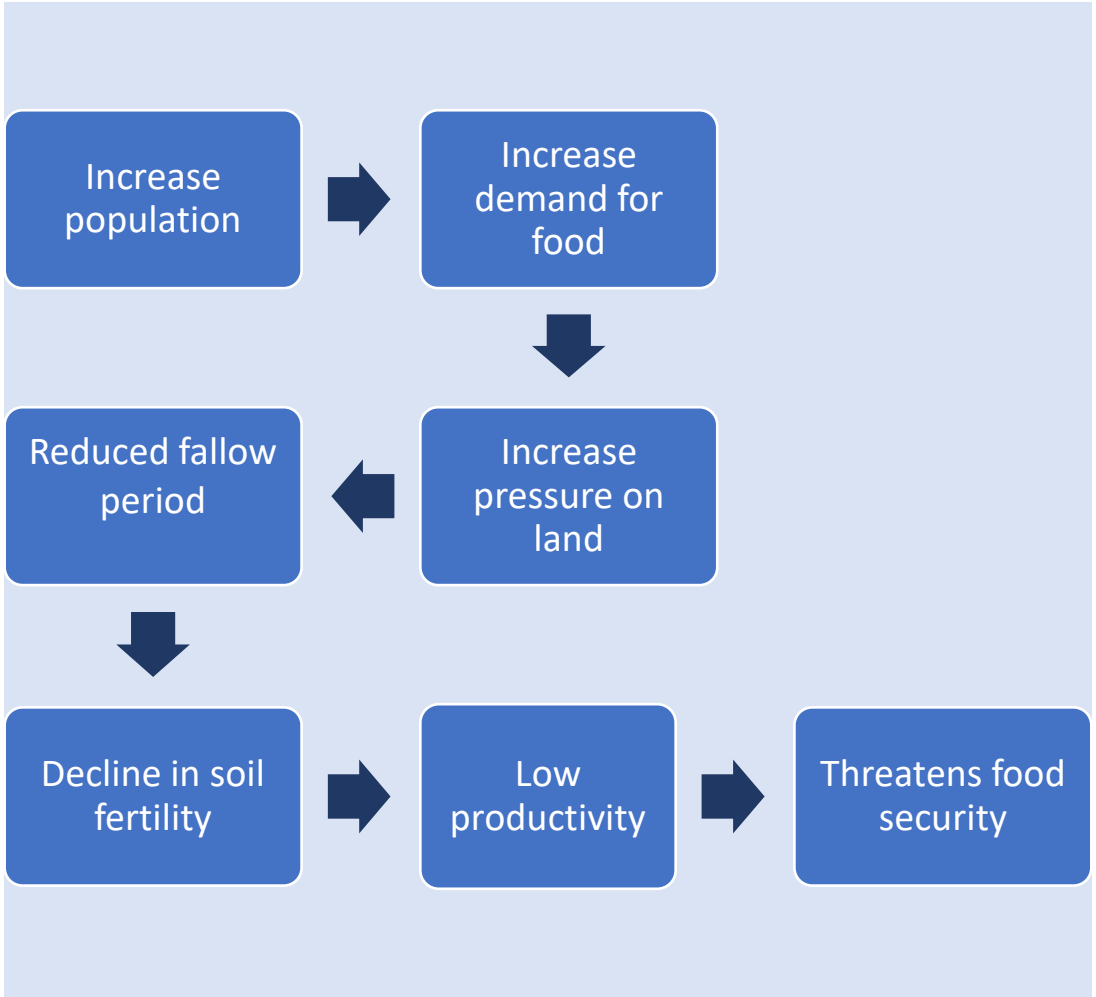
- GM crops are plants that are grown and incorporated into the soil at the same site after 40-60 days of growth to improve the properties of the soil (FAO, 2011).
- Green Manure supplies organic matter in the soil and improves soil health by positively affecting the physical, chemical and biological properties of the soil (Acar et al., 2019).
- Soil organic matter is the source of nitrogen, as well as all nutrients. Nitrogen is a key element in the development of plants and their high-quality yield, (Acar et al., 2019, Talgre et al., 2013).
- The purpose of Green Manure practice is to increase the organic matter and Nitrogen (N) content of the soil for improved crop nutrition and yield.

What are Green manure crops (cont.…)

- ❑ fast growing crops with more foliage and ability to cover the land quickly,
- ❑ high biomass and nutrient accumulation rate,
- ❑ preferably legume in nature and early onset of biological nitrogen fixation
- ❑ low lignin content, low C:N ratio,
- ❑ easy for incorporation and decomposition, and
- ❑ easy and timely release of nutrients,
- ❑ resistant and tolerant to pest and diseases

The need for Green Manure crops

- PNG Food Security Policy 2018-2027 emphasizes on sustainable management of resources including soil and water resources,
- PNG population is estimated at over 8.5 million, 85% of which live in rural communities (FAO-PNG, 2020) and engage in semi-subsistence food production,
- Reduced fallow periods due to an increase in population reduce soil quality and productivity in subsistence fields in PNG (Fujinuma et al., 2018, Dressler et al., 2016),
- Inorganic fertilizers are expensive and may lead to the degradation of natural resources, particularly soils for future generations thus food and nutrition security are at stake,
- Inorganic fertilizers and animal manures are unavailable in many areas in PNG,
- GMs would be a better option than improved fallows in terms of time constraints, resource and nutrients (Hartemink. 2003),
- The role of Green Manures appears to be the most feasible and sustainable option in light of the evolving scenario.



Benefits of Green Manure

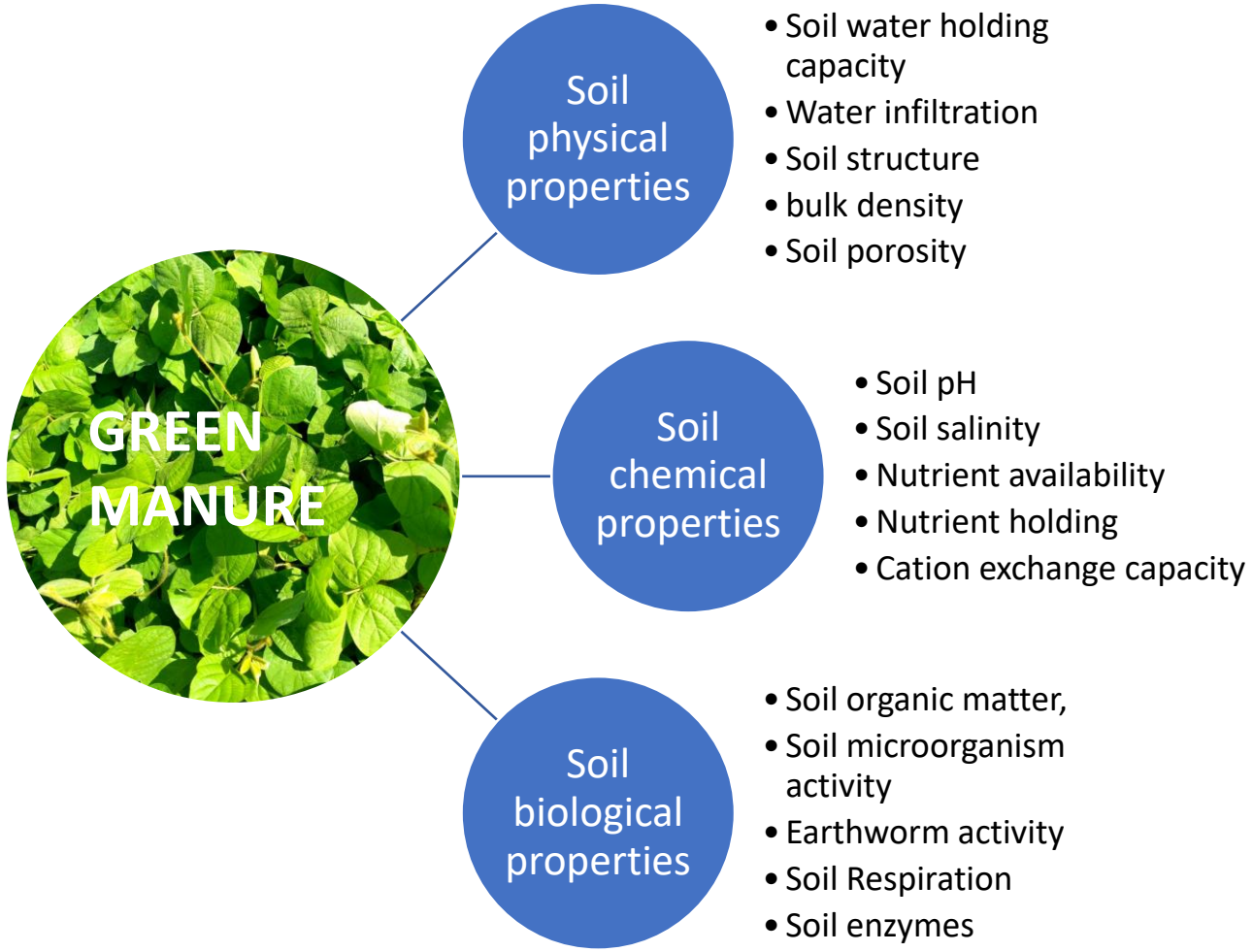
- Benefits of Green manure based on the literature available (Meena et al. 2018, Acar et al.., 2019, Ramanjaneyulu et al., 2021):
- GM crops have higher Nitrogen content and lower C/N ratio, helping in the easy decomposition of organic matter and mineralization for nutrient release at a faster rate
- Fix atmospheric Nitrogen and supply part of it to crops grown in sequence,
- help in the conservation of soil water and reduce soil erosion,
- Reduce the N immobilization risk for succeeding crops,
- reclaim alkaline soils,
- Save Nitrogen fertilizer to be applied to crops,
- Improve the availability of many essential nutrients and enhances nitrogen use efficiency.
- GM practice increased crop yield by 60 - 90% (Kichamu-Wachira et al., 2021, Poku et al., 2014, Laxminarayana et al., 2015)
- Buildup of SOM due to GM incorporation improves soil structure leading to enhanced resistance to erosion, improves root growth of main crops, and increases infiltration and water-holding capacity of the soil. Hence, yields of subsequent main crops increased by around 20 % (Wiesmeier et al., 2015).

Benefits of Green Manure (continued)

Name	***Growth duration (days)***	***Mean Dry matter yield (t/ha)***	***Mean Nitrogen yield (kg ha^{-1})***	***Reference***
Cowpea	40	3.56	74.65	Singh and Shivay, 2016
Lablab	45	3.25	54.5	Abera and Gerkabo, 2020
Velvet bean	56	3.7	97.5	Kaiser Cedric, 2014
Green gram	70	3.92	48.6	Yaqub et al., 2010
Soy bean	50	2.3	59.2	Dabin et al., 2016

Effect of Green Manure on Soil Properties

- ❑ GM improves soil aggregation, water holding capacity, water infiltration, and aeration (Ramanjaneyulu et al., 2021, Meena et al., 2018),
- ❑ GM improves total pore space by decreasing the soil bulk density, and enhancing root development, soil water content, and nutrient use efficiency (Mandal et al. 2003)
- ❑ GM acts as a soil amendment by reducing the pH and alkalinity through the release of humic and acetic acids,
- ❑ GM improves soil organic matter, available nitrogen concentration and reduces its losses through leaching and soil erosion,
- ❑ GM enhances soil microbial biomass and activity and suppresses diseases (Ramanjaneyulu et al., 2021).



Effect of green manure on Soil Properties (cont..)

Soil properties (mean values)	Before GM	After GM	GM type	Reference
pH (H_2O 1:1)	4.5	5.5	Mucuna	Poku et al., 2014
Organic carbon (%)	0.53	0.57	Sesbania aculeata	Singh and Shivay, 2016
Available N (kg ha^{-1})	136	170	Vigna Unguiculata	
Available P (kg ha^{-1})	16.04	18.65	Sesbania sp. aculeata	
Available K (kg ha^{-1})	51	83.9	Sunnhemp	Ossom et al., 2010,
Bulk density (Mg m^{-3})	1.49	1.47	Green gram residue	Mandal et al., 2003
Organic matter (%)	2.41	3.22	Mucuna	Okpara et al., 2004

Effect of Green Manure on crop yield

Green manure	Crop	Mean Yield (t ha^{-1})	Yield response over control (%)	Reference
Calopogonium mucunoides at 20 t ha^{-1}	Sweet corn	16.58	13	Purba et al., 2018
Mucuna pruriens at 30 t ha^{-1}	Carrot root	8.71	80	Poku et al., 2014
Mucuna pruriens at 15 t ha^{-1} + 125 kg NPK	Carrot root	9	85	
Mucuna pruriens at 10 kg ha^{-1} + RD NPK	Sweetpotato	21.1	55	Okpara et al 2004
Cowpea at 1.5 t ha^{-1} + ½ NPK	Sweetpotato	9.08	90.8	Laxminarayana et al., 2015
Recommended Dose NPK	Sweetpotato	9.8	106.1	Laxminarayana et al., 2015
Green gram	rice	4.35	13.6	Salahin et al., 2013

*RD NPK – Recommended Dose Nitrogen, Phosphorus and Potassium

Green manure as an option for climate-smart sustainable agriculture

- Green manure is the most-efficient and sustainable land management practice for soil organic carbon sequestration (Garcia-Franco et al., 2015),
- GM as an organic fertilizer can preserve soil organic matter and is an effective strategy to reduce greenhouse gas emissions in agriculture (Forte et al., 2017).
- Green manure reduce soil N_2O emissions and has lower global warming potential with respect to conventional mineral Nitrogen management (Forte et al., (2017)
- GM using hairy vetch sequesters atmospheric carbon (C) in degraded arable soils which have a high C sequestration potential (Wiesmeier et al., 2015).
- Legume green manure reduces the carbon footprint of crop production by lowering synthetic nitrogen fertilizer needs and replenishing the depleted soil carbon pool. (Yao et al., 2017). This is an efficient way to mitigate climate change.

CHALLENGES IN THE INTEGRATION OF GM IN PNG CROPPING SYSTEMS

- There are major challenges in the integration of GM faced by farmers around the globe (Ramanjaneyulu et al., 2021, Meena et al. 2018):
  - the availability of green manure crop seeds,
  - suitable machinery and technology for the incorporation of green manure crop into the soil
- GM adaptation by farmers is still not a common practice due to:
  - lack of awareness on the benefits,
  - suitability under particular environments and cropping systems,
  - GM being a high-water requiring crop, it may not be suitable for drylands,
  - farmers are concerned about additional costs in terms of labour required,
  - loss of planting window for other commercial crops

CONCLUDING REMARKS:

- Reduced fallow periods due to increase in population reduce soil quality and productivity in subsistence fields in PNG,
- Research to improve the productivity of the subsistence system is needed in PNG because more than 80% of the population engage in semi-subsistence food production,
- Chemical fertilizer is expensive and may lead to degradation of natural resources, particularly soils for future generations thus food and nutrition security are at stake,
- Inorganic fertilizers and animal manures are unavailable in many areas in PNG,
- Improved fallows species may not be beneficial in terms of time constraints, resources and nutrients,
- Incorporation of legume green manure crops has to be encouraged in PNG cropping system for improvement to soil health and crop productivity to make the cropping system more sustainable.

Future Perspectives

- Research for legume green manures is needed on following topics:
  - Awareness and suitability of Green Manure under different environments and cropping systems in PNG,
  - Location-specific cropping system with compatible legume green manure crops either partly or in the window period between two crops,
  - Quantify the contribution of green manuring in Nitrogen fertilizer savings, water saving, increase in crop productivity, and more importantly soil health improvement in PNG cropping systems and
  - Identify easily acceptable incorporation techniques

ACKNOWLEDGEMENT

- This presentation is part of a PhD research study financially supported by the PNG Science and Technology Secretariat and the Postgraduate Research Committee of the PNG University of Technology. The assistance of the staff of the Agriculture Department of the University of Technology is kindly acknowledged.

END OF PRESENTATION,…THANK YOU ALL.