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Sathiya Bama K
Associate Professor (SS&AC), Tamil Nadu Rice Research Institute, Coimbatore, Tamil Nadu, India

V Vasuki
Assistant professor (Agronomy), Institute of Agriculture, Kumulur, Trichy, Tamil Nadu, India

KR Latha
Professor, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

N Ravishankar
Principle scientist, Indian Institute of farming system research, Modipuram, Uttar Pradesh, India

Corresponding Author:
Sathiya Bama K
Associate Professor (SS&AC), Tamil Nadu Rice Research Institute, Coimbatore, Tamil Nadu, India

Climate change mitigation through cropping sequences by prediction of global warming gases

Sathiya Bama K, V Vasuki, KR Latha and N Ravishankar

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Abstract

A research work has been initiated with ten different cropping sequences during 2017-18 in kharif, rabi and summer seasons. In this experiment, prediction was carried out to assess the green house gas emission by adopting cultivation practices for crops including fertilizer usage, energy used for machineries, irrigation and during chemical transport. According to IPCC (2014) prediction based emission factor, in the kharif season crops**,** maize crop consumes more fertilizer, so releases more N_2O (932.52 kg CO_2 equivalent) and least was registered with gingelly (130.55 kg CO_2 equivalent) and field operation (43.06 kg CO_2 equivalent), chemical transport (50.60 kg CO_2 equivalent). During rabi season, The pulse crops such as bengal gram, cowpea, fodder cowpea registered less (93 kg CO_2 equivalent) GHG emission through fertilizer usage and farm operation (11 kg CO_2 equivalent) and sorghum crop releases more energy for farm operation. In summer also the crops which required high fertilizer dose and farm operation emitted more GHG. The cowpea and ground nut observed with less GHG emission of 93kg CO_2 equivalent through fertilizer usage and by farm operation and chemical transport also less GHG registered. Cropping sequence as a whole, lower N_2O emission registered with sorghum-horse gram-ground nut sequence for fertilizer usage, energy emission by farm operation and chemical transport. Bajra Napier (BN) hybrid + desmanthus showed higher feriliser usage as well as higher N_2O emission of 1958 kg CO_2 equivalent. In the energy used for chemical transport, maize-chilli-radish cropping sequence registered higher GHG of 699 kg CO_2 equivalent. For mitigation of climate change carbon sequestration is the process by which, carbon is stored in biomass. Among the different cropping sequences, T8 BN hybrid + desmanthus registered higher CO_2 capture of 84382 kg CO_2 equivalent. In the soil fertility point of view, fodder crops grown soil enrich the soil fertility by improving soil organic carbon, microbial biomass carbon and dehydrogenase activity. High available N was observed in the pulse included cropping sequence.

Keywords: Green house gases; cropping; fertiliser; energy; carbon capture

Introduction

In the last few decades, there was a significant change in the gaseous composition of earth’s atmosphere, mainly through increased energy use in industry and agriculture sectors, viz. deforestation, intensive cultivation, land use change, management practices, etc. These activities lead to increase the emission of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), etc., popularly known as the “greenhouse gases” (GHGs), and rise up the temperature (Bama et al., 2019) [1]. The climatic variation causes changes in the agricultural activity. Season variation expected during 2070 in a country like India is about 0.2–0.4 °C in Kharif and 1.1–4.5 °C during rabi season (Pathak, 2015) [2].

According to IPCC, Greenhouse gases are gaseous constituents of the atmosphere, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the earth's atmosphere. Gases that trap heat in the atmosphere are called greenhouse gases.

Based on the IPCC (2007) [3] guidelines, the sources of GHG emission from crop production are synthetic fertilizers, from direct and indirect nitrous oxide (N_2O) emissions from nitrogen added to agricultural soils by farmers. Specifically, N_2O is produced by microbial processes of nitrification and de-nitrification, taking place on the addition site (direct emission), and after volatilization/re-deposition and leaching processes (indirect emissions).

Next is energy use consist of green house gases (GHG) emissions from direct energy use consists of carbon dioxide (CO_2) associated with fuel (diesel) burning for farm operation and electricity used in agriculture and off-farm emission associated with emission of GHG on the farm consist of production, packaging, storage and distribution of agrochemicals.

Synthetic fertilizer is major source of N_2O emission, which accounted 25 percent. The energy use is the other major source of emission shared the 13 percent of total emission. This source includes diesel and electricity consumption. The next major emitter was off farm emission CO_2 associated with fertilizers, pesticides manufacturing, transportation and storage was 6 per cent.

In the land use management practices, choosing crop or cropping sequence play a major role in altering the soil quality. The crops have the ability to capture carbon di oxide and store it in the soil partly. Drastic improvement in the organic carbon status of the soil by the application of organic manures in the FYM applied on N equivalent basis followed by poultry manure applied treatment was reported by Bama, 2014 and Bama, 2017a) [4, 5]. Bama and Babu (2016) [6] reported that, among the different forage crops, Cumbu Napier grass had higher carbon sequestration potential.

Organic source of nutrients sequestered more carbon in deeper depth than inorganic or intergrated nutrient management in the forage cropping sequences (Bama et al. (2017 b) [7]. Zero tillage recorded higher soil carbon stock than crop establishment method combined with minimum or conventional methods (Bama et al., 2017c) [8]. Another study with different cropping sequences, Bhendi-maize + greengram – Greenmanure improved the passive carbon as well as carbon stock might be due to high organic carbon accumulation in that cropping sequence (Bama et al., 2017a) [5].

Bama and Latha (2017) [9] reported that enforcing the standardization of analytical methods for carbon sequestration studies and explained about the role of land use and management on soil carbon fractions.

Hema et al. (2019) [10] indicated that long-term application of 100% organics exerted significant effect on the active pools of soil organic carbon Aboveground assessment of C stock is direct derivatives of biomass estimates which are often derived by total harvested biomass.

Bama et al. (2017a) [5], bhendi-maize cropping sequence registered higher carbon stock of 11.24 t/ha/yr.

Currently to feed the ever increasing population scientists and farmers are advised to go with continuous cropping. In that case nutrient mining will be a big problem. Also in the continuous cropping, use of synthetic fertilizer leads to increase GHG emission. Benbi et al. (2010) [11] reported that land use and management practice has a greater role in CO_2 emission than fossil fuel burning until the beginning of the twentieth century.

Increasing the level of carbon in agro ecosystem is possible through high biomass producing crops, crop rotation with legumes and following agroforestry systems. Balanced amount of input, litters and organic amendments and losses of carbon through decomposition of organic matter will represents the level of carbon in soil. (Paustian *et al.*, 1997) [12]. Rasmussen *et al.* (1980) [13] suggested that maintaining a dense vegetal cover on the soil surface which could add significant quantity of biomass C to the soil. Consequently, the SOC pool can be effectively managed by addition of crop residues to soil and minimizing the soil erosion.

Gregorich *et al.* (2001) [14] observed that 10 per cent of root residue C was retained in the top 15 cm and 45 per cent, it was below the 15 cm layer for both maize monoculture and maize grown in a legume based rotation. Mixed cropping produced 3 to 5 times more biomass than monoculture, mainly because below ground biomass inputs were higher (Handayani *et al.*, 2002) [15].

Crop rotation sequestrate the C and N in the soil very effectively than the sole culture (Gregorich *et al.*, 2001) [14]. West and Post (2002) [16] calculated from a global database of 67 long-term experiments that enhancing rotation complexity, did not result in sequestering as much on average as did a change to zero tillage, but crop rotation was still more effective in retaining C and N in soil than monoculture.

When addition of C to soil (from crop residue and organic amendments) is higher than losses of C from soil (decomposition, erosion, and leaching) results in accumulation of SOC in cropping systems (Abbas *et al.*, 2012) [17].

Perennial crops showed higher influence on carbon cycling and the overall potential environmental benefits of bioenergy much differently compared to annual crops (Chimento et al., 2016) [18]. Rajput et al. (2015) [19] reported that crop intensification increased C sequestration than the continuous mono cropping. When compared to mono culture growing soybean followed by sun hemp recorded higher carbon sequestration (Seben Junior et al., 2016) [19].

Bama and Babu (2016) [11] reported that, carbon sequestration potential of fodder grasses are higher followed by fodder cereal and fodder legumes in forms of both below ground and above ground carbon removal. Ratnayake *et al.* (2017) [20] reported that crop residue on the surface soil will increase the carbon content on that layer than sub surface layer.

Smyrna (2016) [21] reported the higher carbon stock under Bhendi-Maize+cowpea-sunflower cropping system due to the crop rotation and intercropping followed in that system. Accumulation of organic matter to soil increased the physical, chemical and biological properties of the soil. Decomposition rate of organic matter was affected by the type of carbon input added into the soil and tillage practices (Weil and Magdoff, 2004) [22]. Lal (2004) [23] reported that the fertilization and crop rotation played a significant role in impacting soil C.

Lal (2004) [23] explained that the excessive tillage, low turnover of crop residues and imbalance fertilizer usage were attributed for low level of carbon under the agriculture land use system.

Accumulation of more amounts of biomass and exudates from the root of the maize and wheat led to increase SOC concentration in 0–15 cm. Irrespective of the crop rotation incorporation of crop residue or retention will increase the OM in the soil (Singh *et al.*, 2016) [24].

Enzymes act as a catalyst for all the biochemical process. Dehydrogenase activity (DHA) is commonly used as an indicator of biological activity in soil. Soil’s DHA indicates its potential to support essential biochemical processes. A low oxygen diffusion rate is more favorable for dehydrogenase activity, due to the anaerobic nature, dehydrogenase activity was higher under flooded condition compared to non-flooded condition (Tiwari *et al.*, 1989) [25].

Dehydrogenase enzyme is used as a measure of any negative impact caused by pesticides, trace elements and management practices to the soil (Frank and Malkomes, 1993) [26], as well as a direct measure of soil microbial activity, soils receiving FYM, chemical fertilizer (urea) and have high DHA. Dehydrogenase activities were lower in monoculture (Chu *et* *al*., 2016) [27] where as green manure amended soil had high DHA (Surucu *et al.*, 2014) [28]. Smyrna (2016) [11] reported that highest activity of dehydrogense was recorded in the bhendi-maize+cowpea-sunflower cropping sequence. It was mainly due to more crop residues from the cowpea that would have contributed for increased dehydrogenase enzyme activities.

Here fertilizer usage to agricultural crops plays a major role in nitrous oxide emission. Hence, selection of crops in the cropping sequence or as individual crops is getting important. In this research, work has been done on how the usage of nitrogenous fertilizer, energy used for various farm operation and transport charges for chemicals used were contributed to global warming and influence of cropping on GHG emission and mitigation of climate through carbon storage and other soil fertility advantages were discussed.

Materials and methods

To study the role different cropping practices to mitigate climate change through prediction, a research work was undertaken during the 2017-18. Mitigation potential was worked out for the usage of nitrogenous chemical fertilizers, pesticide usage, number of irrigation, usage of diesel for farm operations based on the emission factor given by IPCC (2014) [29]. Also role of cropping sequences to maintain soil fertility was carried out by determining various soil quality parameters of post harvest soil samples taken from the experiment conducted at Eastern block farm of Tamil nadu Agricultural University Coimbatore, Tamil nadu. The soil moisture regime is Ustic and temperature regime is Isohyperthermic and has montmorrillionitic type of clay. The soils are moderate to well drained and develop cracks during summer. The soil reaction is alkaline and has low to medium soluble salt content. With regard to available nutrient status, the experimental soils are low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in Randomized Block Design with three replications. The initial soil samples were collected and analysed for its nutrient content. The initial soil analysis showed that, soil texture consists of sand (37.6 percent),silt (25.46 percent),clay (36.89 per cent) and comes under clay loam. The soil characteristics analysed are, pH (1:2.5) of 8.30,Electrical conductivity of 0.63 dS/m, soil organic carbon of 5.9 g/kg, microbial biomass carbon of 136.2 (µg/ g soil),available nitrogen content of 244 kg/ha, available phosphorus content of 27.3kg/ha, available potassium content of 545 kg/ha, available sulphur content of 11.7 kg/ha and available micronutrient content of 2.38 ppm, 4.52 ppm,6.28 ppm and 2.62 ppm respectively for Zinc, Manganesh, iron and copper.

Trt.	*kharif*	*rabi*		summer
T_1	Sorghum	Cotton		Ragi
T_2	Onion	Cotton		Maize
T_3	Maize	Bengal gram		Cowpea (G)
T_4	Sorghum	Horse gram		Groundnut
T_5	Gingelly	Bengal gram		Ragi
T_6	Prosomillet	Cowpea (G)		Sunflower
T_7	F. Maize + F. Cowpea	F. Cumbu + F. Cowpea	F. Maize + F. Cowpea	F. Cumbu + F. Cowpea
T_8	BN hybrid (CO (BN) 5) and *Desmanthus (*4:2) (Perennial)			
T_9	Beet root	Cotton		Maize
T_{10}	Maize	Chillies		Raddish

The standard analytical procedures were adopted as per Jackson (1973) [30]. Treatments included are ten different cropping systems as follows. Dehydrogenase enzyme activity analysed by the procedure of Casida Jr *et al. (*1964). Based on the yield data of above ground biomass and on dry weight basis carbon removal was calculated for the different cropping sequences by multiplying with 0.45 (45% of C in drymatter). Based on the root weight of the below ground biomass of plant,carbon removal was calculated for the different cropping sequences by multiplying with 0.45 (45% of C). Though the fodder crops were cultivated perennially, for comparing with the annual crops, each season farm operations and yield were calculated separately.

$$\text{C stock (t ha}^{-1}\text{)} = \text{TOC*BD*D}$$

Results and discussion

Detailed date during the year 2017 -18 from the field experiment was collected after completing one whole cropping sequence comprising three seasons namely kharif, rabi and summer seasons. Post harvest soil samples were analysed for assessing the soil fertility. The table (1) showed the nitrous oxide (N_2O) emission from the nitrogenous fertilizer used for various crops cultivated during kharif 2017-18. Among different crops, according to IPCC prediction based on emission factor (Annexure1) showed that, maize crop consumes more fertilizer, so releases more N_2O (932.52 kg CO_2 equivalent) followed by fodder crops viz., BN hybrid and desmanthus (839.27 kg CO_2 equivalent). Use of nitrogenous fertilizer alone contributes to more than 70% of the N_2O emission. Reducing N usage could reduce the N_2O emission (Bama et al.,2019). The beet root observed with release of 447.61 kg CO_2 equivalent. The fodder maize + fodder cowpea, onion, and prosomillet cropping released same amount of nitrous oxide of 223.80 kg CO_2 equivalent. Among the crops tried in this research, least was registered with gingelly (130.55 kg CO2 equivalent) next to sorghum which recorded 186.50 kg CO2 equivalent.

Energy used for machineries which includes farm operation like ploughing, harrowing etc., and electricity used for irrigation and GHG emitted during production of farm chemicals such as fertilizer, pesticides and fungicides. Among the different crops, BN hybrid and desmanthus cultivation required more of field operation (96.88 kg CO_2 equivalent) followed by maize which required 86.11 kg CO_2 equivalent and sorghum (69.97 kg CO_2 equivalent). Onion which required 53.82 kg CO_2 equivalent. Least release of N_2O of 43.06 kg CO_2 equivalent from gingelly field operation (Bama,2017) [32].

In the case of energy used for chemical transport of fertilizer, pesticides, herbicides maize requires more 376 kg CO_2 equivalent (due to high fertilizer consumption followed by BN hybrid and desmanthus (292.50 kg CO_2 equivalent). Least amount of energy was used by gingelly crop of 50.60 kg CO_2 equivalent. Totally by combining fertilizer usage, enegy used for farm operation and chemical transport, maize crop releases more of GHG interms of kg CO_2 equivalent followed by BN hybrid and desmanthus of 1229 kg CO_2 equivalent and beet root (668 kg CO_2 equivalent). Least GHG was registered in 224 kg CO_2 equivalent.

In terms of mitigation of climate change, carbon sequestration is an important process through which carbon can be captured through biomass and stored in soil for quit long time. Among the different crops tried, BN hybrid (57060 kg CO_2 equivalent) captured more of CO_2 from atmosphere followed by Fodder Maize +fodder cowpea (41210 kg CO_2 equivalent) and then Onion (11607 kg CO_2 equivalent). Bama and Babu (2016) [6] reported that Cumbu Napier grass had higher C sequestration potential of above-ground biomass which removed 336.7 t CO2/ha than multicut fodder sorghum (148.7 t CO2/ha). They also reported that, the belowground biomass C removal in Cumbu Napier grass (7.73 t CO2/ha) from the atmosphere than Lucerne (4.21 t CO2/ha). When subtracting GHG emission from CO_2 captured for each crop, the result showed that, all crops have negative effect on global warming potential (table1). Comparatively fodder crops viz., BN hybrid and fodder maize + fodder cowpea captured more of carbon besides adding more of below ground biomass than other crops. This is also line with (Bama and Babu, 2016; Bama and Somasundaram, 2017; Bama, 2016; Bama, 2017; Bama et al., 2013) [6, 33, 34, 32, 35].

The nitrous oxide (N_2O) emission from the nitrogenous fertilizer used for various crops cultivated during rabi 2017-18 are depicted in Table (2). Among different crops, according to IPCC prediction based on emission factor showed that, BN hybrid and desmanthus releases more N_2O (560 kg CO_2 equivalent) followed by chilli crop (448 kg CO_2 equivalent). The cotton crop registered with 298 kg CO2 equivalent. The horse gram observed with GHG emission of 47 kg CO_2 equivalent The pulse crops such as Bengal gram, cowpea, fodder cowpea registered with 93 kg CO_2 equivalent of GHG emission through fertilizer usage.

Farm operation like ploughing, harrowing etc., and electricity used for irrigation and GHG emitted during production of farm chemicals such as fertilizer, pesticides and fungicide are comes under energy sector. Among the different crops, pulses such as Bengal gram, horse gram and Bengal gram cultivation required less energy (11 kg CO_2 equivalent) followed by cowpea which required 22 kg CO_2 equivalent while sorghum requires high energy (69.97 kg CO_2 equivalent). Other crops like fodders crops, cotton and chilli required 54 kg CO_2 equivalent in field operation

In the case of energy used for chemical transport of fertilizer, pesticides, herbicides BN hybrid requires more 195 kg CO_2 equivalent (due to high fertilizer consumption) followed by cotton (104 kg CO_2 equivalent). Least amount of energy was used by horse gram crop of 16 kg CO_2 equivalent. Totally by combining fertilizer usage, enegy used for farm operation and chemical transport, fodder crops such as BN hybrid and desmanthus crop releases more of GHG (808 kg CO_2 equivalent) followed by chilli (708 kg CO_2 equivalent) and cotton (456 kg CO_2 equivalent). Least GHG was registered in horse gram (224 kg CO_2 equivalent).

Through carbon sequestration carbon can be captured through biomass and stored in soil for quit long time. Among the different crops tried, BN hybrid and desmanthes (18055 kg CO_2 equivalent) captured more of CO_2 from atmosphere followed by fodder maize +fodder cowpea (14738 kg CO_2 equivalent) and chilli (7999 kg CO_2 equivalent). When subtracting GHG emission from CO_2 captured for each crop, all crops have negative effect on global warming potential. Comparatively fodder crops viz., BN hybrid and fodder maize + fodder cowpea and chill crops captured more of carbon besides adding more of below ground biomass than other crops (table2).

The table (3) shows the, nitrous oxide (N_2O) emission from the nitrogenous fertilizer used for various crops cultivated during summer 2017-18. Among different crops, according to IPCC prediction based on emission factor showed that, maize releases more N_2O (933 kg CO_2 equivalent) followed by BN hybrid and desmanthus crop (560 kg CO_2 equivalent). The ragi and sunflower crops registered 224 kg CO_2 equivalent followed by radish. The cowpea and ground nut observed with GHG emission of 93kg CO_2 equivalent of GHG emission through fertilizer usage.

Energy used for farm operation and electricity used for irrigation and GHG emitted during production of farm chemicals such as fertilizer, pesticides and fungicide are accounted. Among the different crops, BN grass and desmanthus cultivation required more energy due to high irrigation requirement (54 kg CO_2 equivalent) followed by maize, ragi and sunflower which required same amount of energy required for cultivation of 22 kg CO_2 equivalent and ground nut (16 kg CO_2 equivalent). Lower energy consumed for fodder cowpea and cowpea and radish (11 kg CO_2 equivalent)

Energy used for chemical transport of fertilizer, pesticides, herbicides showed that, maize requires more 325 kg CO_2 equivalent (due to high fertilizer consumption) followed by BN hybrid and desmanthus (195 kg CO_2 equivalent), ragi (83 kg CO_2 equivalent) and sunflower (78 kg CO_2 equivalent. Least amount of energy was used by ground nut, cowpea and fodder cowpea crop of 33 kg CO_2 equivalent. Totally by combining fertilizer usage, enegy used for farm operation and chemical transport, maize crop releases more of GHG interms of kg CO_2 equivalent (1279) followed by BN hybrid and desmanthus (808 kg CO_2 equivalent). Least GHG was registered in fodder maize and fodder cowpea (137 kg CO_2 equivalent) (table30.

Carbon can be captured through carbon sequestration and stored in soil for long time. Among the different crops tried, fodder maize and fodder cowpea (12146 kg CO_2 equivalent) captured more of CO_2 from atmosphere followed by BN hybrid and desmanthus (9266 kg CO_2 equivalent) and maize (9145 kg CO_2 equivalent). When subtracting GHG emission from CO_2 captured for each crop, the result showed that, all crops have negative effect on global warming potential. Comparatively fodder crops viz., BN hybrid crop captured more of carbon besides adding more of below ground biomass than other crops.

Cropping sequence as a total, irrespective of seasons, the sources and sink of GHG are depicted in fig. 1 to 4 and table 4. Among the sequences, T8 (BN hybrid + desmanthus) showed higher feriliser usage as well as higher N_2O emission of 1958 kg CO_2 equivalent followed by beet- cotton -maize sequence T9 of 1679 kg CO_2 equivalent and the lower N_2O emission registered with sorghum-horse gram-ground nut sequence T4 (326 kg CO_2 equivalent) (fig1). Energy used for chemical transport for cropping sequences is given in fig.2 revealed that, T10 maize-chilli-radish registered higher GHG of 699 kg CO_2 equivalent followed by BN hybrid with desmanthus (683 kg CO_2 equivalent) T8. The lower GHG was emitted by T4 sorghum-horse gram-ground nut (114 kg CO_2 equivalent) for chemical transport. The figure 2 also showed that, cropping sequence T5 gingelly- bengal gram –ragi used lower energy for field operation and irrigation. Higher energy usage by machineries recorded in the T8 BN hybrid with desmanthus followed by T1 sorghum-cotton-ragi and by T9 beet root-cotton –maize cropping sequence. By combining all the GHG sources for crop cultivation which includes, fertilizer usage, energy used for machineries and chemical transport for all three seasons as sequence showed that, (T8) cropping BN hybrid + desmanthus proned to release higher value of 2845 kg CO_2 equivalent followed by T9 beet root – cotton –maize (2403 kg CO_2 equivalent) and (T10) maize-chilli-radish (2400 kg CO_2 equivalent. The lower GHG emission was predicted in T4 sorghum-horse gram-ground nut (537 kg CO_2 equivalent).

For mitigation of climate change carbon capture is the process by which, carbon is stored in biomass. Among the different cropping sequences, T8 BN hybrid + desmanthus registered higher CO_2 capture of 84382 kg CO_2 equivalent followed by T7 fodder maize+fodder cowpea of 68095 kg CO_2 equivalent. The lower biomass CO2 capture was recorded with T4 sorghum-horse gram-ground nut (6027 kg CO_2 equivalent).

Apart from environmental point of you, cropping sequences have their own effect on soil fertility parameters. The results are given in table5. The results reveal that, the physico chemical properties do not influenced by the different crops. Significant variation of pH under different cropping sequence not noticed. The higher organic carbon content (5.98 g/kg) and available phosphorus (22.0 kg/ha) was recorded in the T8 treatment**.** Soil organic carbon plays an important role in the soil quality by decreasing the bulk density, increasing the aggregate stability, cation exchange capacity, nutrient cycling and biological activity. The T_7 (fodder maize+fodder cowpea) showed the comparable amount of soil organic carbon (5.82 g/kg), which is mainly due to the high amount of biomass. This in line with Kaur *et al.* (2008). Bama and Babu (2016) reported that, the Cumbu Napier fodder crop stored 9.2 g/kg of SOC over initial SOC status of 6.5 g/kg. In the present study also revealed higher enzyme activity of 37.4 (µg triphenylformazon g^{-1}soil/day) and microbial biomass carbon (134.2 µg/g) were found in these cropping sequences could have contributed for the improvement of SOC. Smyrna (2016) [11]also reported that the improved SOC might be due to improved microbial population and residue addition in the Bhendi-maize+cowpea-sunflower cropping sequence. The inclusion of legumes in the cropping sequence stores more carbon (Yazhini et al., 2019) [36].

Higher available nitrogen (274 kg/ha) was recorded in the maize-bengal gram – cowpea cropping sequence. It might be due to the inclusion of nitrogen fixing legume in the cropping sequence. It might be due to the inclusion of legume as sole crop in the cropping sequence which fixed more atmospheric nitrogen contributed for nitrogen addition to soil. This is supported by yazhini et al. (2019) [36] and Bama et al. (2020) [37], that inclusion of legume with crop rotation increase the soil fertility by fixing the atmospheric nitrogen in the root nodules. Availability of nitrogen increased for the succeeding crops by the process of mineralization **(**Palm *et al.*, 1988) [38]. Bhuiyan and Zaman (1996) [39] also reported that the increased available nitrogen by inclusion of leguminous green manure.

The higher available phosphorus (22.0 kg/ha) was recorded in the T8 treatment. It might be due to the higher organic matter accumulation and further by decomposition could have released the organic acid and it would have released the phosphorus from unavailable form to available form. This is line with Anwar *et al.* (2005). Inclusion of leguminous green manure and legume in the cropping sequences might be the reason for higher availability of the phosphorus by the transfer of unavailable to available phosphorus while fixing nitrogen. Sinha *et al.* (2014) [40] also supports that fixation of biological nitrogen in the root nodules needs energy (ATP) so, the unavailable form of phosphorus could converted into the available form by the rhizobia which were present in the root nodules. The higher available potassium of 569 kg/ha was recorded in the Sorghum –Cotton-Ragi treatment. In the present study among different cropping sequences, T_8 (BN hybrid +desmanthus) and T_7 (Fodder maize and fodder cowpea) observed higher enzyme activities of It activity might be due to increased organic matter addition and root exudation by inclusion legume in the cropping sequence. Also high level of labile and water soluble carbon present in these cropping sequence be act as a energy sources of the micro organism which increase the microbial population and inturn enzymatic activity of soil. This is in line with Babu *et al.* (2005) [41]. Okur *et al.* (2009) [42] observed positive relationship between organic C and dehydrogenase activity. Dehydrogenases were greatly associated with microbial biomass, which in turn mediates the decomposition of organic matter (Zhang *et al.*, 2010) [43]. (Kumar *et al.*, 2010) [44] reported that DHA activity was enhanced by addition of organic manures (table5).

Conclusion

Based on the present work on prediction of green house gas emission by fertilizer usage, energy usage, chemical transport and mitigation of GHG by carbon storage by different cropping sequences and its effect on soil quality, two different conclusion could be drawn. In environmental point of view of sequestering carbon and soil carbon maintenance in the soil, the forage crops BN hybrid and desmanthus and in view of reduced fertilser usage, energy usage and farm chemical use and crop production to feed the population, gingelly-bengal gram-ragi/prosomillet-cowpea-sunflower could be recommended.

Table 1: Influence of different crops cultivated during kharif season on global warming potential and carbon sequestration

Crops	Sources of GHG (kg CO_2 equivalent)				Sink of GWG CO_2 captured Through biomass (5)	GWP (source-sink) (4-5)	Net CO_2 eq captured
	N_2O emission from fertilizer and manures (1)	Energy used for machineries (2)	Chemicals transport (3)	Total CO_2 emission (4) 1+2+3			
Sorghum	186.50	69.97	65.00	321	4563	-4241	4241
Onion	223.80	53.82	78.00	356	11607	-11252	11252
Maize	932.52	86.11	325.00	1344	8493	-7149	7149
Sorghum	186.50	69.97	65.00	321	3587	-3266	3266
Gingelly	130.55	43.06	50.60	224	5230	-5006	5006
Proso millet	223.80	48.44	78.00	350	4928	-4577	4577
F. Maize + F. Cowpea	223.80	64.58	78.00	366	41210	-40844	40844
BN hybrid and *Desmanthus*	839.27	96.88	292.50	1229	57060	-55832	55832
Beet root	447.61	64.58	156.00	668	16196	-15528	15528
Maize	932.52	69.97	376.00	1378	4789	-3410	3410

Table 2: Influence of different crops cultivated during rabi season on global warming potential and carbon sequestration

Crops	Sources of GHG (CO_2 equivalent)				Sink of GWG. CO_2sequestered Through biomass (5)	GWP (source-sink) (4-5)	Net CO_2 eq sequestered
	N_2O emission from fertilizer and manures (1)	Energy used for machineries (2)	Chemicals transport (3)	Total CO_2 emission (4) 1+2+3			
Cotton	298	54	104	456	3367	-2911	2911
Cotton	298	54	104	456	3240	-2784	2784
Bengal gram	93	11	33	137	1597	-1461	1461
Horse gram	47	11	16	74	768	-694	694
Bengal gram	93	11	38	142	1555	-1413	1413
Cowpea (G)	93	22	33	147	2643	-2496	2496
F. Maize + F. Cowpea (6:2)	93	54	33	180	14738	-14559	14559
BN hybrid (CO (BN) 5) and *Desmanthus*	560	54	195	808	18055	-17247	17247
Cotton	298	54	104	456	3186	-2730	2730
Chillies	448	54	207	708	7999	-7290	7290

Table 3: Influence of different crops cultivated during summer season on global warming potential and carbon sequestration

crops	Sources of GHG (CO_2 equivalent)				Sink of GWG. CO_2sequestered Through biomass (5)	GWP (source-sink) (4-5)	Net CO_2 eq sequestered
	N_2O emission from fertilizer and manures (1)	Energy used for machineries (2)	Chemicals transport (3)	Total CO_2 emission (4) 1+2+3			
Ragi	224	22	78	323	3044	-2720	2720
Maize	933	22	325	1279	9145	-7866	7866
Cowpea (G)	93	11	33	137	2900	-2764	2764
Groundnut	93	16	33	142	1672	-1530	1530
Ragi	224	22	83	328	3361	-3033	3033
Sunflower	224	22	78	323	2229	-1905	1905
Fodder Maize +Fodder. Cowpea (6:2)	93	11	33	137	12146	-12010	12010
BNgrass (CO (BN) 5) *Desmanthus*	560	54	195	808	9266	-8458	8458
Maize	933	22	325	1279	8061	-6782	6782
Radish	187	11	116	313	15756	-15443	15443

Table 4: Influence of different cropping sequences as a whole on global warming potential and carbon sequestration

Sources of GHG (CO_2 equivalent)						Sink of GWG. CO_2sequestered Through biomass (5)	GWP (source-sink) (4-5)	Net CO_2 eq sequestered
Treatments	Fertiliser usage by cropping (total of 3 crops)	N_2O emission from fertilizer and manures (1)	Energy used for machineries (2)	Chemicals transport (3)	Total CO_2 emission (4) 1+2+3			
T1	190	709	145	247	1101	10973	-9872	9872
T2	390	1455	129	507	2091	23993	-21902	21902
T3	300	1119	108	390	1617	12991	-11374	11374
T4	87.5	326	97	114	537	6027	-5490	5490
T5	120	448	75	171	694	10146	-9452	9452
T6	145	541	91	189	821	9799	-8978	8978
T7	110	410	129	143	682	68095	-67413	67413
T8	525	1958	205	683	2845	84382	-81537	81537
T9	450	1679	140	585	2403	27444	-25040	25040
T10	420	1567	135	699	2400	28544	-26143	26143

Table 5: Effect of cropping systems on Available soil nutrient status (kg/ha) at the end of the cropping cycle

Treatments	pH	EC	SOC (%)	MBC (µg/g)	Ava. N (kg/ha)	Ava. P (kg/ha)	Ava. K (kg/ha)	Dehydrogenase enzyme (µg triphenylformazon g^{-1}soil/day)
T_1	8.48	0.32	5.52	122.5	262	21.4	569	29.5
T_2	8.41	0.4	5.42	115.0	252	20.6	548	31.5
T_3	8.36	0.39	5.65	118.4	**274**	21.6	565	32.8
T_4	8.54	0.29	5.70	115.3	269	20.6	558	33.2
T_5	8.5	0.27	5.62	105.3	248	20.8	560	30.4
T_6	8.41	0.32	5.58	107.2	248	21.3	552	30.2
T_7	8.48	0.37	5.82	131.6	246	20.7	548	28.5
T_8	8.45	0.4	5.98	134.2	248	22.0	568	37.4
T_9	8.42	0.35	5.61	128.5	236	21.2	542	35.5
T_{10}	8.38	0.29	5.54	126.4	238	21.0	532	35.6
CD (p=0.05)	NS	NS	0.32		12	1.2	29	2.1
Initial	8.42	0.58	0.57	108.5	252	22.5	562	3.8

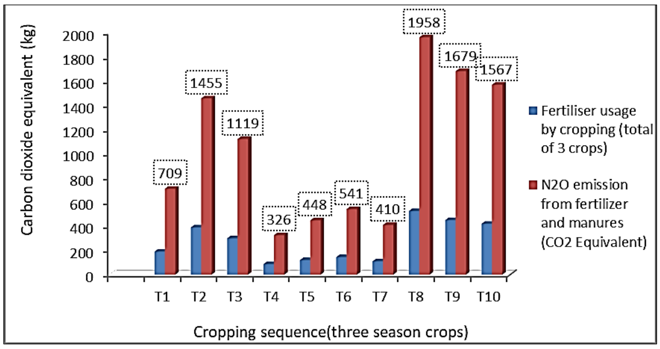

Fig 1: Sources of GHG emission in cropping sequences through fertiliser usage in CO2 equivalent (kg)

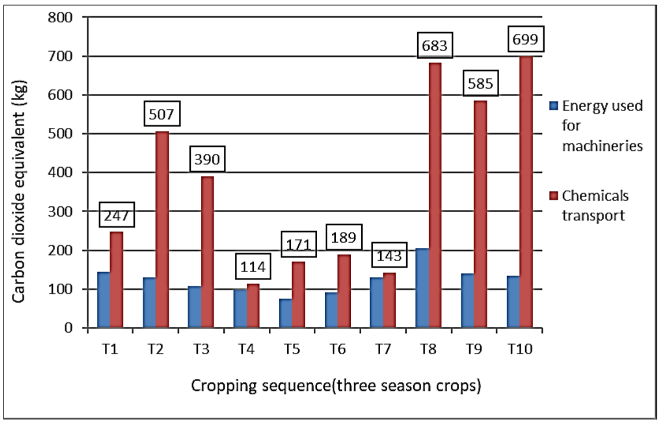

Fig 2: Sources of GHG emission in cropping sequences through energy used and chemical transport in CO_2 equivalent (kg)

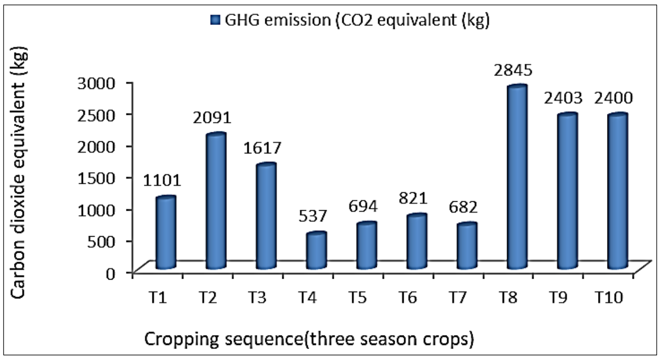

Fig 3: GHG emission by cultivating different cropping sequences (all sources and three seasons) in CO_2 equivalent (kg)

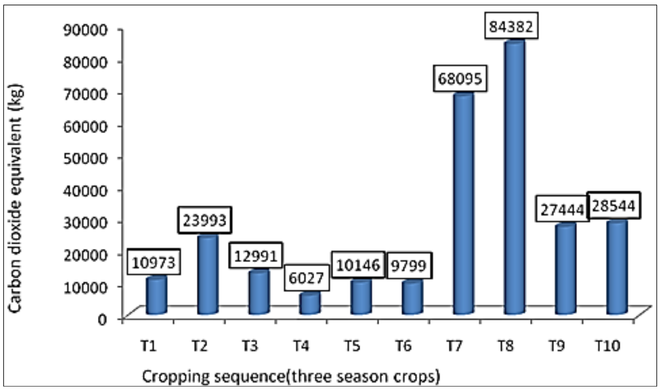

Fig 4: Carbon dioxide captured in different cropping sequences (All three seasons) in CO_2 equivalent (kg)

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