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Estimation of sequestered carbon of rice and wheat at district level for Chhattisgarh plains zone of Chhattisgarh State of India

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Abstract
Rice (*Oryza sativa* L.), a widely cultivated cleistogamous cereal crop with chromosome number, n=12, 2n = 24, belongs to the genus Oryza, the family Graminaceae (poaceae) (Syed and Khaliq, 2008). The whole Chhattisgarh is divided into 3 zones according to Agro-Climatic Zones *viz.* (i)Chhattisgarh Plains Zone (CPZ). (ii) Northern Hills Zone (NHZ) and (iii) Bastar Plateau Zone (BPZ).The Chhattisgarh total 33 District.The area under study only Baloda-Bazar District has been taken for study. To calculate the above ground and below ground biomass along with carbon for rice and wheat, some factors have been. The AGB, BGB and TBM for rice crop is 13,86,307 (t ha^{-1}), 3,46,576.7(t ha^{-1}), 1,732,883(t ha^{-1}) respectively. Similarly, the AGB, BGB and TBM for wheat crop is 13,724 (t ha^{-1}), 3431.11(t ha^{-1}), 17,155.56(t ha^{-1}) respectively and The ACC, BCC and TCC for rice crop is 5,82,248.8 (t ha^{-1}), 1,31,699.1 (t ha^{-1}), 7,13,947.9 (t ha^{-1}) respectively. Similarly, the ACC, BCC and TCC for wheat crop is 5,764.26 (t ha^{-1}), 1303.82 (t ha^{-1}), 7,068.08 (t ha^{-1}) respectively.

Keywords: Above Ground Biomass (AGB), Below Ground Biomass (BGB), Total Biomass (TBM), Above Carbon Content (ACC), Below Carbon Content (ACC), Total Carbon Content (ACC) etc.

Introduction
Rice (*Oryza sativa* L.), a widely cultivated cleistogamous cereal crop with chromosome number, n=12, 2n = 24, belongs to the genus *Oryza*, the family Graminaceae (poaceae) (Syed and Khaliq, 2008). Global demands for major grains such as wheat (*Triticum aestivum* L.), the family *poaceae* are projected to increase by 70% by 2050 (Tilman *et al.* 2011) [32] chromosome number, n=21, 2n = 42 (Tiwari *et al.* 2022) [33]. Rice is one of the most significant food grain crops in the world, more than 2.7 billion people used as basic diet (Anonymous, 2020) [16]. India holds the largest area, total production of rice during 2022-23 is estimated at *(record)* 1308.37 lakh tonnes, The production of Wheat (record) in the country is estimated at 1121.82 lakh metric tonnes which is higher by 44.40 lakh metric tonnes as compared to previous year's production. (https://pib.gov.in/PressReleseDetail.aspx?PRID=1899193#main-nav), an increase of 2.71 percent over 2019 in terms of area and 0.37 percent in terms of production (Thakur *et al*. 2022) [31].
India is the second-largest producer of rice in the entire world, after China. Rice is grown extensively in India in an area of about 43.19 million hectares with an annual production of 110.15 MT and an average yield of 2412 t ha^{-1} (Directorate of Economics and Statistics, DAC&FW, 2021). India's production of food grains has been increasing every year, and India is the world's largest producer of pulses with the per cent share of 24.60 and ranks as the second largest producer of rice and wheat with the percent share of 21.60 and 11.50 respectively; both accounts the production of 118.87 and 107.86 million tonnes on the land of 43.66 and 31.36 million hectare during 2019-20. India shares more than 26, 14 and 70 per cent area and 16, 14 and 78 per cent of production of rice and wheat to the world (Wasnik *et al.* 2022) [35]. The state of Chhattisgarh is the 16th most populous and 10th largest in terms of area in India. It is also recognized as a major producer of rice. 43 percent of the state's total arable land is under cultivation, and about 70 percent of the population works in agriculture. One of the main crops is paddy.

With a population of more than 2.55 billion, the geographical area is approximately 136 lakh ha, with 46.51 lakh ha of cultivable land and 60.76 lakh ha of forest land (Jaiswal *et al.* 2023) [23].

The State of Chhattisgarh, known as the "Rice bowl of India". The maximum area is covered with paddy during kharif and contributes a substantial part to the national paddy output (Anonymous, 2021) [14]. The state is fully reliant on the monsoon with a yearly rainfall of 1200-1600 mm. In Chhattisgarh, rice is cultivated in an area of 3.79 million hectares with a production of 91.03 lakh tonnes and productivity of 2400 t ha^{-1} (Thakur *et al.* 2022) [31].

A census of the biomass on Earth is key for understanding the structure and dynamics of the biosphere. However, a global, Tuantitative view of how the biomass of different taxa compare with one another is still lacking. Here, we assemble the overall biomass composition of the biosphere, establishing a census of the ≈550 gigatons of carbon (Gt C) of biomass distributed among all of the kingdoms of life. We find that the kingdoms of life concentrate at different locations on the planet; plants (≈450 Gt C, the dominant kingdom) are primarily terrestrial, whereas animals (≈2 Gt C) are mainly marine, and bacteria (≈70 Gt C) and archaea (≈7 Gt C) are predominantly located in deep subsurface environments (Yinon *et al.* 2018) [37]. Biomass meets a major fraction of the energy demand in rural areas of most developing countries. For example, in India, the share of biomass energy use (from various biomass resources, *i.e.* agricultural residues, animal dung, firewood, etc.) is about 46% of the total energy consumption (Tripathi *et al.* 1998) [34].

The carbon cycle is the process that moves carbon between plants, animals, and microbes, minerals in the earth, and the atmosphere. Carbon is the fourth most abundant element in the universe. With its ability to form complex molecules such as DNA and proteins, carbon makes life on Earth possible. Carbon in the form of carbon dioxide (CO_2) is also an important part of our atmosphere, where it helps to control the Earth's temperature. Because only a tiny number of atoms reach the Earth from space, our planet is called a closed system. This means the Earth does not gain or lose carbon. But carbon does move constantly. Most carbon on Earth is stored in rocks and sediments. The rest is in the ocean, atmosphere, and in living organisms. Scientists use the term "carbon sinks" to refer to places where carbon is stored away from the atmosphere. Plants constantly exchange carbon with the atmosphere. Plants absorb carbon dioxide during photosynthesis and much of this carbon dioxide is then stored in roots, permafrost, grasslands, and forests. Plants and the soil then release carbon dioxide when they decay. Other organisms also release carbon dioxide as they live and die. For example, animals exhale carbon dioxide when they breathe and release carbon dioxide when they decompose. The oceans also exchange carbon with the atmosphere by absorbing carbon, which then sinks as it cools. In addition, carbon is stored in rocks and other geological deposits. For example, coal and other fossil fuels are made of carbon from plants that has beenstored under the Earth's surface for millions of years. (https://www.energy.gov/science/doe-explainsthe-carbon cycle#:~:text=Plants%20absorb%20carbon%20dioxide%20during,carbon%20dioxide%20when%20they%20decay)

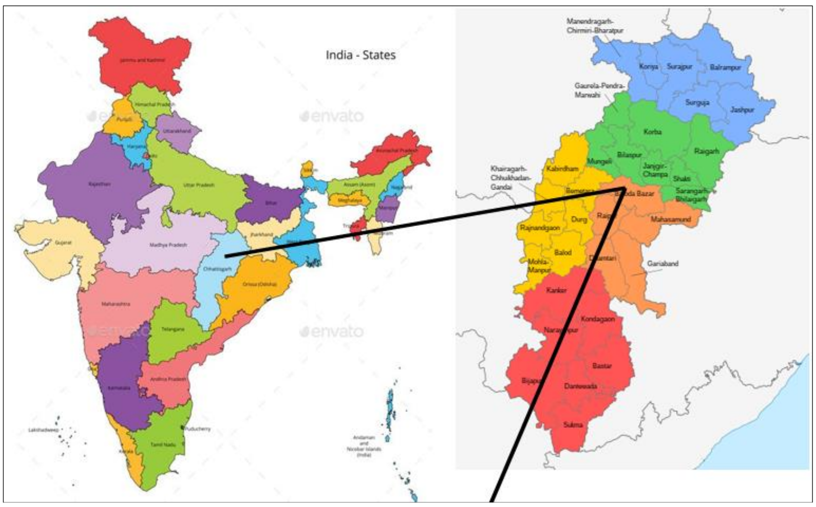
Crop growth and yield depends on the fixed carbon content and their distribution to plant parts (Ex.:- roots and shoots)(Amanullah, 2018) [12]. Understanding and calculating the total carbon content accumulated in field crops is very important due to the current issues of food security and global warming (Amanullah *et al.* 2019) [4]. However, there is a lack of research that shows how much carbon content is partitioned into the roots and shoots (Amanullah *et al.* 2020) [2]. (Amanullah *et al.* 2021) [20] Our previous research work confirmed that the increase in carbon content in plant tissues (roots and shoots) depends on total dry matter accumulation and partitioning, (Irving L.J. 2015) [22] because plant growth and yield correlates with net carbon gain on a whole plant basis (Kruger E.L., and Volin J.C. 2006) [24]. The IPCC report revealed that about 1.2 billion tonnes of carbon at annual rate of 4% could be stocked every year for the sustainability of agricultural systems (IPCC. 2014) [21]. As the crop growth and yield depends on the total carbon content of plants, therefore, any agronomic practices that help the plants to sequester more atmospheric CO_2 (photosynthesis) increases the Total carbon content accumulation in plants in its distribution to below ground carbon content to roots (BCC) and above ground carbon content to shoots (ACC) (Amanullah. 2023) [1].

Materials and Methods

Study area

The whole Chhattisgarh is divided into 3 zones according to Agro-Climatic Zones *viz.* (i) Chhattisgarh Plains Zone (CPZ). (ii) Northern Hills Zone (NHZ) and (iii) Bastar Plateau Zone (BPZ).The Chhattisgarh total 33 District.The area under study only Baloda-Bazar District has been taken for study.

The area under study which is situated at 21.6571° N, latitude and 82.1612° E longitude.



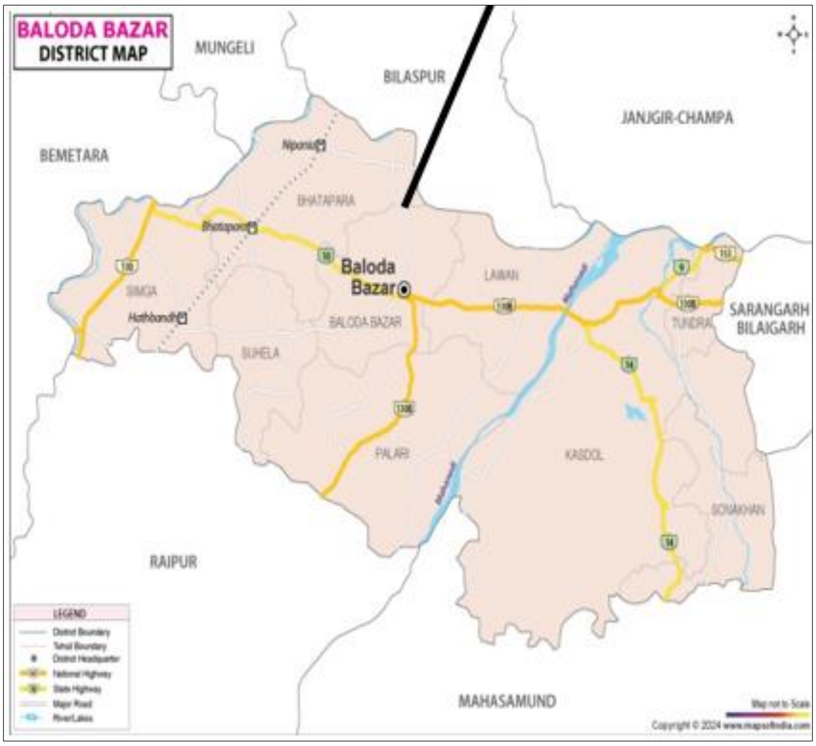


Fig 1: Map of the study area

Estimationof total carbon content (TCC) accumulation and its distribution above ground (shoots) and below ground (roots) parts in major cereals like rice and wheat. For the estimation of the total carbon content (TCC) accumulated by plants and its distribution (partitioning) into above ground (shoots) and below ground (roots) parts, efforts were made to calculate the two important factors for above ground parts (ACC) and below ground parts (BCC); to estimate the AGB, BGB and Total Biomass along with carbon, the following factors and equations has been used (Amanullah. 2023) [1]:

AGB = GP ÷ 0.45 ……………….(1)

TBM = AGB × 1.25 ………………..(2)

BGB = TBM × 0.20 ………………..(3)

ACC = AGB× 0.42 ………………..(4)

BCC = BGB× 0.38 ………………..(5)

TCC = ACC + BCC ………………..(6)

Where:-
AGB= Above Ground Biomass
GP = Grain Production (t ha^{-1})
TBM= Total Biomass
BGB= Below Ground Biomass
ACC= Above Ground Carbon Content
BCC= Below Ground Carbon Content
TCC = Total Carbon Content
0.45 = Constant Factor for AGB.
1.25 = Constant Factor for TBM.
0.20 = Constant Factor for BGB.
0.42 = Constant Factor for ACC.
0.38 = Constant Factor for BCC.

Area, Production and Productivity of rice crop and wheat crop has been procured from the site of agriculture department of Chhattisgarh. The total area (in ha), production (in tonnes) and productivity (tons ha^{-1}) for the rice crop in Baloda bazar district at the year 2021-22 is recorded 2,43,319; 6,23,838 and 2.56 respectively. Similarly, the total area (in ha), production (in tonnes) and productivity (tons ha^{-1}) for the wheat crop in Baloda bazar district at the year 2021-22 was recorded as 4,913; 6,176 and 1.26 respectively. (https://data.desagri.gov.in/website/crops-apy-report-web).

The TCC accumulation in crop plants and its partitioning into above ground parts (ACC) and below ground parts (BCC) depends on these three major factors: (1) plant genotypes (species, varieties, hybrids, growth habit, growth stages); (2) agronomic practices (chemical fertilizers, organic fertilizers, biofertilizers, plant nutrition, irrigation, tillage practices, soil types, SOC, plant density, seed rates, sowing time, *etc.*); and (3) environmental condition viz. biotic stresses (plant competition, weeds, diseases, insects, pests, *etc.*) and abiotic stresses (low and high temperature stress, low and high water stress, light quality and duration, wind, chemicals, gases, soil pollution, water pollution *etc.*) (Amanullah *et al.* 2015) [10]. Total dry matter accumulation and its partitioning into roots and shoots depends on plant nutrition (Yao *et al.* 2015) [36], light availability (Poorter *et al.* 2012) [27], soil types (Amanullah. 2014) [13], plant competitions (Amanullah *et al.* 2016) [8], organic sources (Nadia *et al.* 2023) [26], beneficial microbes (Amanullah *et al.* 2019) [4], plant species (Redin *et al*. 2018) [29], plants genotypes (Amanullah and Inamullah 2016) [8], plant tissues (Bert D. and Danjon F. 2006) [18], and plant growth stages (Amanullah and Stewart B. A. 2015.) [10], *etc*.

The differences in the TCC accumulation and its partitioning into ACC and BCC in different crop species under study may be attributed to the differences in genetic makeup and differences in plant heights, leaf area, leaf area index and crop growth rate, water and nutrients use efficiency (Amanullah and Stewart B.A. 2013). Bagrintseva and Nosov 2012 [17] and Mut *et. al.* 2006 [25] reported changes in the total biomass accumulation in different crops. Therefore, crops which could sequester more carbon above (shoots) and below ground (roots) indicating more carbon dioxide sequestration from the atmosphere and therefore the cultivation of these crops could help reduce global warming. Therefore, plant breeder's efforts to produce crop species and ideotypes with higher TCC accumulation could be useful. As the cereals are executive crops (Amanullah *et al*. 2019) [4], so the use of sustainable soil management practices (FAO. 2019) [20], could also increase the TCC accumulation and reduce CO_2 in the atmosphere (FAO Outlook. 2018) [19]. For increasing TCC accumulation in plants and it's partitioning into ACC and BCC it is important to (1) select high yielding plants genotypes, (2) use best agronomic (management) practices and (3) planting of crops in suitable environmental conditions. The best agronomic practices that improve crop growth and development, increase grain and total biomass thus increase TCC in different rice crop species. Any biotic or abiotic stress that could reduce the productivity (yield or biomass) of field crops could reduce the TCC and its partitioning into ACC and BCC under different environments. The agronomists study various crop production problems and work for better soil and crop management practices to obtain higher yield.

Result

Estimation of Total Biomass (AGB & BGB) and Total Carbon Content ha^{-1} from Rice crop in Baloda bazar

In 2021-2022, (Amanullah *et al.* 2020) [2] rice produced in tonnes (t) and the total carbon content (CC) fixed in rice below (BCC) and above (ACC) ground parts for the world leading countries was calculated (Powlson *et. al.* 2011) [28]. For example, in 2021-2022 the total rice produced in Baloda bazar District was 6,23,838 tonnes (t ha^{-1}). The above ground biomass (AGB) or shoots dry weight (shoot biomass) was calculated using Eq:

AGB = Grain Production ÷ 0.45
= 6,23,838 ÷ 0.45
= 13,86,307 (t ha^{-1})
The carbon content of the AGB or shoot CC (ACC) has been calculated

ACC = AGB× 0.42
= 13,86,307 × 0.42
= 5,82,248.8 (t ha^{-1})
The total biomass (TBM) (shoots + roots) has been calculated

TBM = AGB × 1.25
= 13,86,307 ×1.25
= 1,732,883 (t ha^{-1})
The below ground biomass (BGB) or root biomass has been calculated

BGB = TBM × 0.20
= 1,732,883× 0.20
= 3,46,576.7 (t ha^{-1})
The CC of the BGB or root biomass (BCC) has been calculated

BCC = BGB× 0.38
= 3,46,576.7 × 0.38
= 1,31,699.1 (t ha^{-1})
The total Carbon Content (TCC) fixed by rice in Baloda bazaar during 2021-2022 has been calculated

TCC = ACC + BCC
= 5,82,248.8 + 1,31,699.1
= 7,13,947.9 (t ha^{-1})
The study area has been AGB, BGB and TBM for rice crop is 13,86,307(t ha^{-1}), 3,46,576.7(t ha^{-1}), 1,732,883(t ha^{-1}) and Similarly, ACC, BCC and TCC for rice crop is 5,82,248.8 (t ha^{-1}), 1,31,699.1 (t ha^{-1}), 7,13,947.9 (t ha^{-1}) respectively.

Estimation of Total Biomass (AGB & BGB) and Total Carbon Content ha^{-1}from Wheat crop in Baloda bazar

In 2021-2022 (Amanullah *et al.* 2020) [2], wheat produced in tonnes (t) and the total carbon content (TCC) accumulated and partitioned into roots or below ground CC (BCC) and shoots, or above ground CC (ACC) for the Baloda bazar District was calculated through this model (Powlson *et. al.* 2011) [28]. For example, in 2021-22, the total wheat produced in Baloda bazarwas6, 176 tonnes (T). The above ground biomass (AGB) or shoot dry weight (shoot biomass) has been calculated

AGB = Grain Production ÷ 0.35
= 6,166 ÷0.35
= 13,724 (t ha^{-1})
The carbon content of the AGB or shoot CC (ACC) has been calculated

ACC = AGB× 0.42
= 13,724 ×0.42
= 5,764.26 (t ha^{-1})
The total biomass (TBM) (shoots + roots) has been calculated

TBM = AGB × 1.25
= 13,724 ×1.25
= 17,155.56 (t ha^{-1})
The below ground biomass (BGB) or root biomass has been calculated

BGB = TBM × 0.20
= 17,155.56× 0.20
= 3431.11(t ha^{-1})
The CC of the BGB or root biomass (BCC) has been calculated

BCC = BGB× 0.38
= 3431,11×0.38
= 1303.82 (t ha^{-1})
The total CC (TCC) fixed by wheat in Baloda bazar during 2021-2022 has been calculated

TCC = ACC + BCC
= 5764.26 + 1303.82
= 7,068.08 (t ha^{-1})

The study area has been AGB, BGB and TBM for wheat crop is 13,724 (t ha^{-1}), 3431.11(t ha^{-1}), 7,068.08(t ha^{-1}) and Similarly, the ACC, BCC and TCC for wheat crop is 5,764.26 (t ha^{-1}), 1303.82 (t ha^{-1}), 7,068.08 (t ha^{-1}) respectively.

Conclusions

The increase in carbon sequestration (1 kg of carbon is equal to 3.67 kg of CO_2) through the process of photosynthesis in field crops is essential to combat the issue of food security and global warming. However, the lack of simplified and easy way of carbon estimation restricts researchers to estimate data on total carbon content (TCC) sequestered or captures by the field crops and it's partitioning into roots and shoots. In this study, highly simplified calculations have been developed to provide easy estimation of carbon content in below-ground parts (BCC) and above-ground parts (ACC) of various field crops, including Rice and wheat. Best agronomic practices that improve or increase the rate of photosynthesis under field conditions significantly increase the capture or sequestration carbon. Crops with higher TCC took more CO_2 (higher photosynthetic efficiency) from the atmosphere therefore increase the yield per unit area and decrease the negative impacts of global warming and food security. The simplified approach for carbon content (CC) estimation utilized in this study can be highly beneficial for researchers and students. It allows for easy estimation of the carbon content fixed in the roots and shoots of diverse field crops, including Rice and wheat. The total carbon content (TCC) in plants exhibited a positive correlation with total biomass. Furthermore, both belowground carbon content (BCC) and above-ground carbon content (ACC) demonstrated a positive association with TCC. It was confirmed from the model, that out of the total 100% TCC accumulation by field crops, 82% is partitioned into ACC (shoots) and 18% into BCC (roots). The practices that increase grain yield, harvest index, and total biomass increased carbon content in roots and shoots of different crop species. The best agronomic practices that increase grain yield in field crops per unit area will also increase the TCC accumulation and it's portioning into ACC and BCC. Selecting carbon superior genotypes of crop species along with best management practices including sustainable soil management practices will significantly reduce CO_2 emission and increase soil health, productivity and sustainability with more carbon sequestration into the soils.

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