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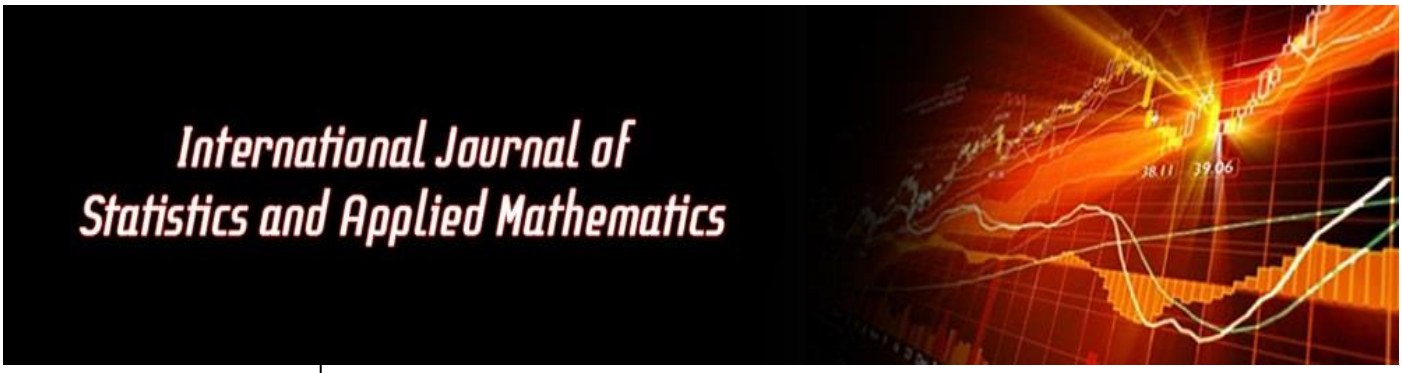

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Correlation and regression studies of vegetation Biomass and CO_2 equivalent Carbon stock under wheat - *Eucalyptus teretocornis* based agroforestry system

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Abstract
Agroforestry is a combination of practicing agriculture and forestry together on the same unit of land. *Eucalyptus tereticornis* (family – Myrtaceae) is highly use full and important economic species in commercial forestry due to its fast growing and short rotation period. The present investigation was conducted in *Eucalyptus tereticornis* and wheat based agroforestry system with different weed control methods to find out correlation of CO_2 equivalent C stock with various biomass of agroforestry component such as wheat biomass, weed biomass, fresh bole wt of tree, above tree biomass, total tree biomass, total biomass (tree + crop) under agroforestry system. In experiment plot 5 major weeds was found with wheat crop. The correlation analysis revealed that the biomass of different component with CO_2 equivalent C stock (t ha^{-1}) showed positive correlation during both the year and pooled analysis. It indicated that total biomass (Tree + Crop) had highest positive correlation during first year (0.885) and pooled mean (0.745) whereas, above tree biomass and total tree biomass (0.765 and 0.765) showed higher positive correlation equally during second year. The linear increase in CO_2 equivalent C stock was predicted with wheat biomass, weed biomass, fresh bole wt, above tree biomass, total tree biomass, total biomass (tree + crop) and vegetation carbon pool t ha^{-1}. The increase in CO_2 equivalent carbon stock could be predicted by 0.240 and 2.804, 2.148 and 4.758, 1.883 and 1.149, 1.818 and 1.185, 1.443 and 0.940, 2.635 and 1.770, 3.670 and 3.150 t ha^{-1} during both the year under wheat and *Eucalyptus teretocornis* based agroforestry system.

Keywords: *Eucalyptus tereticornis*, Biomass, carbon stock, correlation, regression

Introduction
Agroforestry is a practice of combining agriculture and forestry on same land. It is ideal land use option to increase its production ability, increase tree cover outside forest area and reduce anthropogenic pressure on natural forests. It is also viable option for mitigation of climate change. Many agroforestry system involving various combination of tree component and agriculture crops have been evolved and successfully tried in field with increased economic and ecological benefits. Eucalyptus based agroforestry system are now commercially agroforestry system and popular amongst growers.

Eucalyptus is fast-growing tree for biomass production in the tropics, providing resources for the pulp and paper industries and bioenergy. Eucalyptus is the most popular choice to be planted along the edges or bunds of agricultural fields, and it appears to be well incorporated and accepted in agroforestry in India (Cavalli *et al.* 2022, Nair, PKR 1993) [4, 12]. Despite of its adaptability to different agro-climatic condition, is monoculture may be somewhat risk prone. Intercropping of suitable agriculture crop with *E. tereticornis* can there for be a better option as it not only reduces the economic risks associated with monoculture by generating extra income but it also result in improved productivity per unit area as a result of more efficient utilization of solar radiation and available soil nutrient.

A number of agriculture crop are grown combination with *Eucalyptus tereticornis* and wheat one of them. Wheat is also an important cereal crop of Madhya Pradesh. It is worldwide staple food. Wheat is grown over more land area any other food crop.

Wheat (*Triticum aestivum* L.) is widely intercropped cereal crop during *rabi* season (November - April) with Eucalyptus, Poplar, and other fast growing tree species in Northern states of India *viz.*, Uttarakhand, Punjab, Haryana, Uttar Pradesh and Bihar, parts of Central and Eastern states such as Madhya Pradesh, Chhattisgarh and West Bengal (Nural-lslam and Johanson, 1987) [13].

In addition to the significant amount of carbon stored in aboveground biomass, agroforestry systems also store carbon in belowground biomass. Agricultural lands are believed to be a major carbon sink and could absorb large quantities of carbon (C), if trees are integrated with crop and judiciously managed together with crops and/or animals. Agroforestry has importance as a biological mitigation strategy for climate change because its carbon storage potential in aboveground, belowground biomass,

Present investigation has been undertaken during the year 2016-17 and 2017-18 to study the association of vegetation biomass in different component of agroforestry such as weeds, wheat and tree with carbon dioxide equivalent carbon stock under *Eucalyptus tereticornis* based agroforestry system.

Materials and Methods

The field experiment was conducted at farmer's field at Village - Majitha, Block – Shahpura, District - Jabalpur under the supervision of department of Forestry JNKVV Jabalpur during *Rabi* season of 2016 -2017 and 2017 - 2018.

Data collection and statistical analysis

The study was undertaken with carbon dioxide equivalent carbon stock the objective of finding out association among biomass of agroforestry *viz*, The linear increase in CO_2 equivalent C stock was predicted with wheat biomass, weed biomass, fresh bole wt, above tree biomass, total tree biomass, total biomass (tree + crop) and vegetation carbon pool under agroforestry system.

Analysis of interdependence and correlation among different vegetation biomass is an important aspect of variation and selection studies. During the present investigation correlation and regression analysis among the various variable was done using the standard procedure Sendecor and Cochran (1967) [14]. The correlation and regression study gives an insight in to the complex relationship between different growth characters in biological system.

In such biological system each variable influences the other variables. Ordinarily in a simple statistical analysis variable are classified into predictor (independent) and criterion (dependent) variables. A predictor variable is used to predict an outcome and the criterion variable are also called response variable.

During the present investigation the data of various vegetation biomass such as wheat, weed and tree was collected from the field was subjected to statistical analysis. A correlation matrix is a table sowing correlation coefficient between sets of variable. Each random variable in the table correlate each other values in the table. This allows one to be see witch pairs have the highest correlation. Of course the diagonal of the table is always a set of ones because the correlation between a variable and it self is always 1.

The correlation matrix amongst different crop growth characters and crop yield was calculated as suggested by Sendecor and Cochran (1967) [14] with the following formula.

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{N}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{N}\right)}}$$

In order to predict the effects of weeds on yield of wheat crop regression models were used and coefficient was correlated to interpret quantitative change in yield. The following regression equation was used $\hat{Y} = a + bx$.

Where,

$\hat{Y}$ = CO_2 equivalent C stock and standard out come

X = Tree / crop biomass / independent variable

A and b are regression constant and regression coefficient, respectively.

Result and Discussion

Tree / crop biomass with CO_2 equivalent C stock (t ha^{-1})

The data shown on table No 1 described about the zero order correlation matrix of CO_2 equivalent C stock with biomass of different component under agroforestry system during the first year (2016-17), second year (2017-18) and pooled at the age of four and five year of tree respectively. The biomass of different component with CO_2 equivalent C stock (t ha^{-1}) showed positive correlation during both the year and pooled analysis. It indicated that total biomass (Tree + Crop) had highest positive correlation (0.885) during first year and pooled mean (0.745) whereas, above tree biomass and total tree biomass (0.765 and 0.765) showed higher positive correlation equally during second year under agroforestry system. The total biomass (tree + crop) also showed the higher positive correlation with vegetation carbon pool (0.885) during first year and pooled mean (0.825) whereas, above tree biomass and total tree biomass (0.854 and 0.854) showed higher positive correlation equally with vegetation carbon pool during second year. The correlations between CO_2 equivalent carbon stock verses biomass, were also reported by Mulugeta *et al*. (2009) [11]. His study showed positive relationship between carbon sequestration with diameter, height and biomass of *Eucalyptus globules.* Another example from Antonio and Rodrigues (2011) [2] who also found a significant increase in the predictive ability of biomass estimation models for eucalyptus when including height as an additional predictor to diameter.

Amongst increase the biomass of different component of agroforestry system, the linear increase in CO_2 equivalent C stock was predicted with wheat biomass, weed biomass, fresh bole wt, above tree biomass, total tree biomass, total biomass (Tree + Crop) and vegetation carbon pool (t ha^{-1}) during both the year (Table 2). The increase in CO_2 equivalent C stock could be predicted by 0.240 and 2.804, 2.148 and 4.758, 1.883 and 1.149, 1.818 and 1.185, 1.443 and 0.940, 2.635 and 1.770, 3.670 and 3.150 t ha^{-1} during both the year.

The pooled mean of two year revealed that linear increase in CO_2 equivalent C stock was predicted with wheat biomass, weed biomass, fresh bole wt, above tree biomass, total tree biomass, total biomass (tree + crop) and vegetation carbon pool t ha^{-1}. The increase in CO_2 equivalent C stock could be predicted by 1.689, 1.299, 0.907, 0.997, 0.791, 1.523 and 3.311 t ha^{-1} under wheat- *Eucalyptus tereticornis* based agroforestry system (Table2 and Figure3). High value of regression coefficient and coefficient of determination provided evidence for effective prediction of CO_2 equivalent carbon stock in eucalyptus plantation under different land use systems in similar conditions. The results are in conformity with the finding of Bala *et al*. (2012) [3] and Jesus *et al*. (2005) [8].

Table 1: Correlation between tree / crop biomass with CO_2 equivalent C stock (t ha^{-1})

Character	Weed biomas (t ha^{-1})	Fresh bole wt (t ha^{-1})	Above tree biomass (t ha^{-1})	Total Tree Biomass (t ha^{-1})	Total (Tree + Crop) biomass (t ha^{-1})	Vegetation Carbon Pool (t ha^{-1})	CO_2 equivalent C stock (t ha^{-1})
	X_2	X_3	X_4	X_5	X_6	X_7	Y
2016-17							
X_1- Wheat biomass (t ha^{-1})	-0.753*	0.160NS	0.013NS	0.011NS	0.255NS	0.050NS	0.049NS
X_2- Weed biomass (t ha^{-1})		-0.101NS	0.123NS	0.125NS	0.124NS	0.345NS	0.345NS
X_3- Fresh bole wt (t ha^{-1})			0.901**	0.901**	0.819**	0.739*	0.740*
X_4- Above tree (t ha^{-1})				1.000**	0.921**	0.806**	0.806**
X_5-Ttotal tree (t ha^{-1})					0.921**	0.805**	0.806**
X_6- Total biomass (tree + crop) (t ha^{-1})						0.885**	0.885**
X_7- Vegetation Carbon pool (t ha^{-1})							1.000**
2017-18							
Character	X_2	X_3	X_4	X_5	X_6	X_7	Y
X_1- Wheat biomass (t ha^{-1})	-0.822**	0.424NS	0.367NS	0.367NS	0.506NS	0.425NS	0.429NS
X_2- Weed biomass (t ha^{-1})	1	-0.508NS	-0.507NS	-0.508NS	-0.525NS	-0.557NS	-0.547NS
X_3- Fresh bole wt (t ha^{-1})		1	0.977**	0.977**	0.974**	0.754*	0.647*
X_4- Above tree (t ha^{-1})			1	1.000**	0.976**	0.854**	0.765**
X_5-Ttotal tree (t ha^{-1})				1	0.976**	0.854**	0.765**
X_6- Total biomass (tree + crop) (t ha^{-1})					1	0.841**	0.758*
X_7- Vegetation Carbon pool (t ha^{-1})						1	0.985**
Pooled							
Character	X_2	X_3	X_4	X_5	X_6	X_7	Y
X_1- Wheat biomass (t ha^{-1})	-0.791**	0.491NS	0.369NS	0.368NS	0.551NS	0.477NS	0.446NS
X_2- Weed biomass (t ha^{-1})		-0.472NS	-0.376NS	-0.376NS	-0.354NS	-0.324NS	-0.266NS
X_3- Fresh bole wt (t ha^{-1})			0.953**	0.953**	0.926**	0.653*	0.546NS
X_4- Above tree (t ha^{-1})				1.000**	0.941**	0.776**	0.678*
X_5-Ttotal tree (t ha^{-1})					0.941**	0.776**	0.678*
X_6- Total biomass (tree + crop) (t ha^{-1})						0.825**	0.745*
X_7- Vegetation Carbon pool (t ha^{-1})							0.982**

Table 2: Regression between tree /crop biomass with CO_2 equivalent C stock (t ha^{-1})

Character	$\hat{Y}$= a + bx	R^2
2016-17		
X_1- Wheat biomass (t ha^{-1})	$\hat{Y}$ = 212.7+ 0.240 X_1	R^2 = 0.002
X_2- Weed biomass (t ha^{-1})	$\hat{Y}$ = 212.4+2.148 X_2	R^2 = 0.119
X_3- Fresh bole wt (t ha^{-1})	$\hat{Y}$ = - 51.48-1.883 X_3	R^2 = 0.547
X_4- Above tree (t ha^{-1})	$\hat{Y}$ =- 72.34+ 1.818 X_4	R^2 = 0.649
X_5-Ttotal tree (t ha^{-1})	$\hat{Y}$ =- 72.31+ 1.443 X_5	R^2 = 649
X_6- Total biomass (tree + crop) (t ha^{-1})	$\hat{Y}$ =- 75.68+2.635 X_6	R^2 = 0.782
X_7- Vegetation Carbon pool (t ha^{-1})	$\hat{Y}$ =- 0.051+ 3.670 X_7	R^2 = 1
2017-18		
X_1- Wheat biomass (t ha^{-1})	$\hat{Y}$ = 252.1+ 2.804 X_1	R^2 = 0.183
X_2- Weed biomass (t ha^{-1})	$\hat{Y}$ = 271.8-4.758 X_2	R^2 = 0.299
X_3- Fresh bole wt (t ha^{-1})	$\hat{Y}$ = 66.16+ 1.149 X_3	R^2 = 0.419
X_4- Above tree (t ha^{-1})	$\hat{Y}$ = 30.16+ 1.185 X_4	R^2 = 0.585
X_5-Ttotal tree (t ha^{-1})	$\hat{Y}$ = 30.20+0.940 X_5	R^2 = 0.585
X_6- Total biomass (tree + crop) (t ha^{-1})	$\hat{Y}$ =26.39+1.770 X_6	R^2 = 0.573
X_7- Vegetation Carbon pool (t ha^{-1})	$\hat{Y}$ =35.88+ 3.150 X_7	R^2 =0.970
Pooled		
X_1- Wheat biomass (t ha^{-1})	$\hat{Y}$ = 230.6+ 1.689 X_1	R^2 = 0.199
X_2- Weed biomass (t ha^{-1})	$\hat{Y}$ =242.4-1.299 X_2	R^2 = 0.070
X_3- Fresh bole wt (t ha^{-1})	$\hat{Y}$ = 97.54+ 0.907 X_3	R^2 =0.298
X_4- Above tree (t ha^{-1})	$\hat{Y}$ = 62.58+0.997 X_4	R^2 = 0.46
X_5-Ttotal tree (t ha^{-1})	$\hat{Y}$ = 62.50+0.791 X_5	R^2 = 0.459
X_6- Total biomass (tree + crop) (t ha^{-1})	$\hat{Y}$ = 53.41+ 1.523 X_6	R^2 = 0.554
X_7- Vegetation Carbon pool (t ha^{-1})	$\hat{Y}$ = 22.48+ 3.311 X_7	R^2 = 0.964

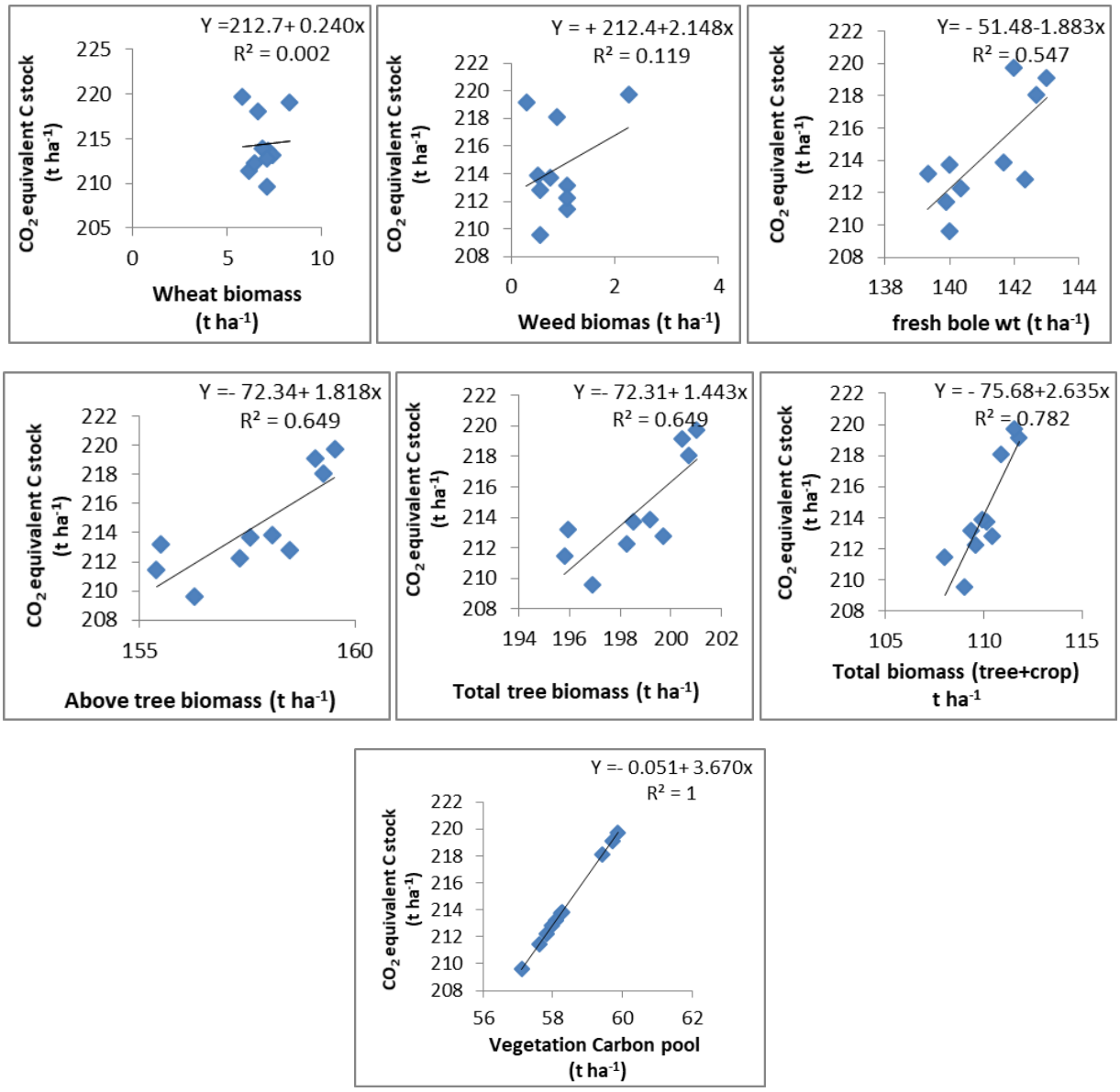
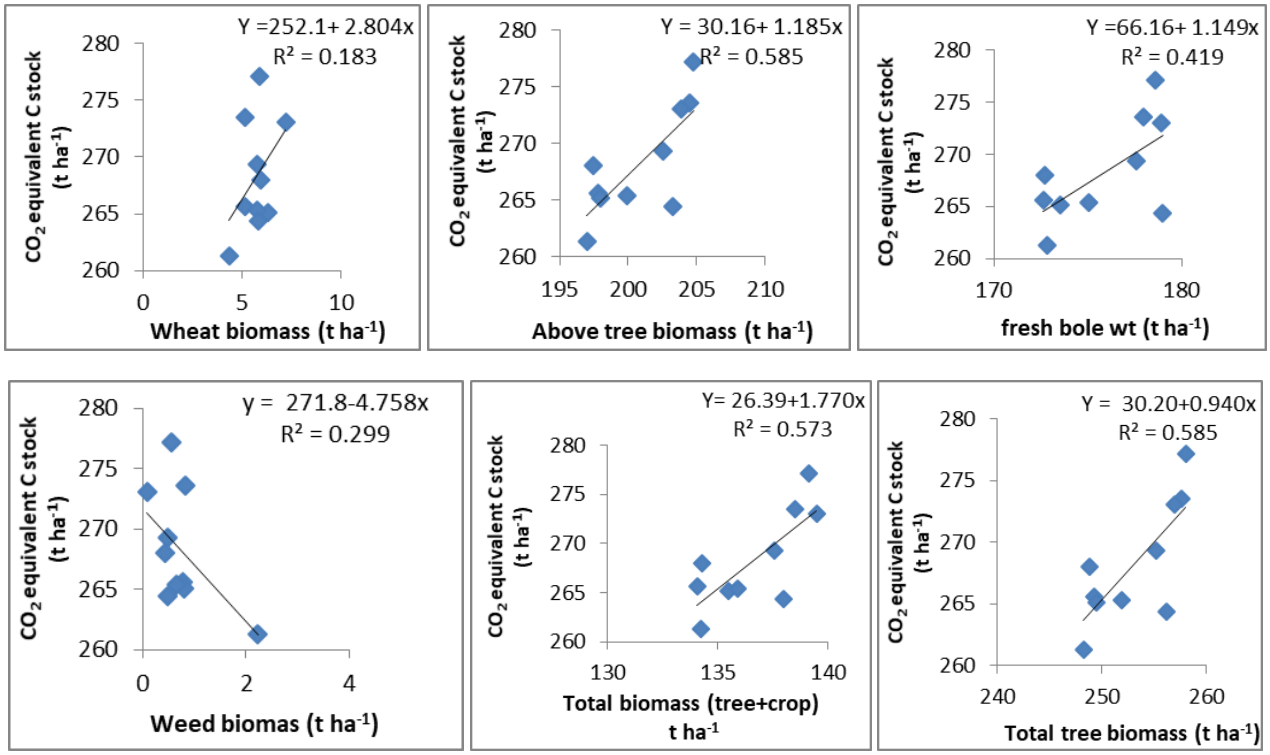


Fig 1: Regression between tree / crop biomass with CO_2 equivalent C stock (t ha^{-1}) during first year (2016-17)



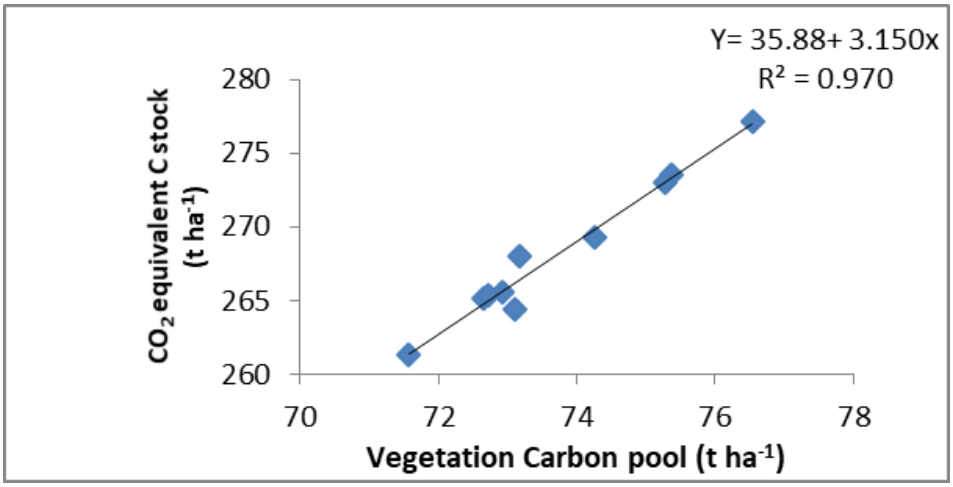
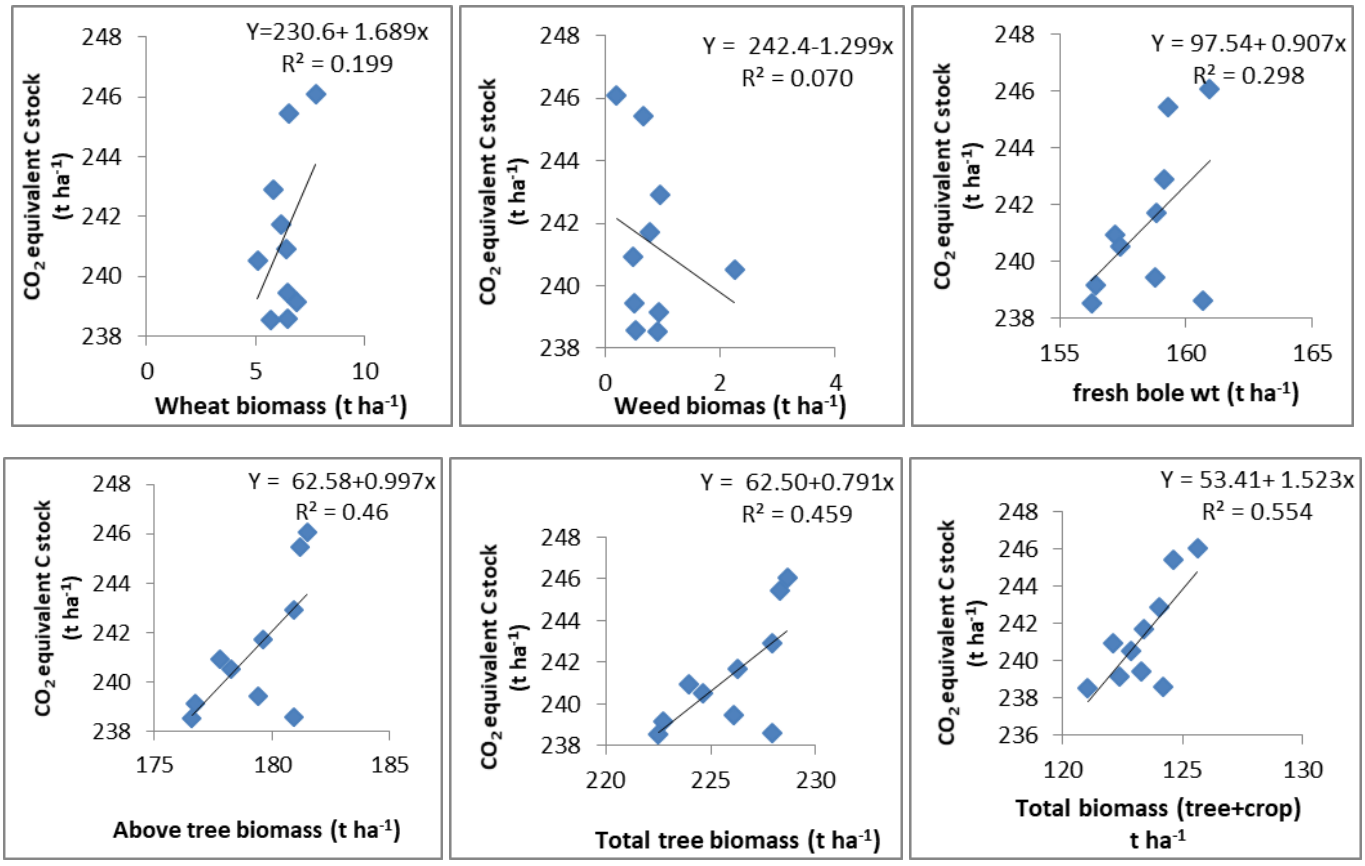


Fig 2: Regression between tree / crop biomass with CO_2 equivalent C stock (t ha^{-1}) during second year (2017-18)



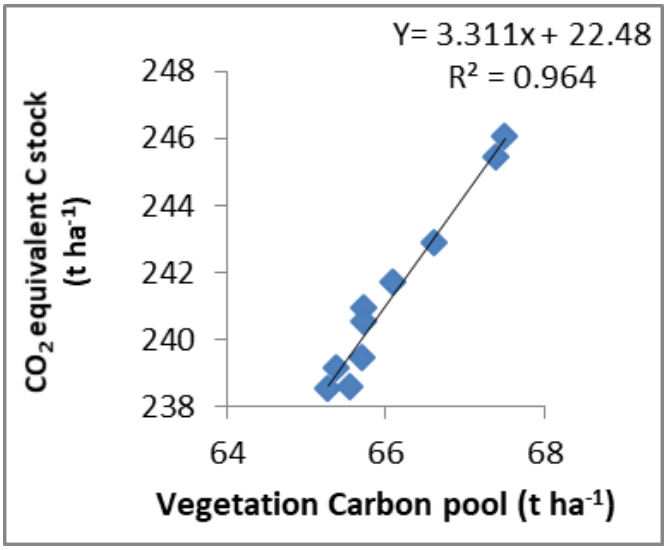


Fig 3: Pooled regression between tree / crop biomass with CO_2 quivalent C stock

Conclusion

It can be concluded from the forgoing analysis that vegetation biomass have positive association in carbon dioxide equivalent carbon stock and vegetation carbon pool. The total biomass (tree + crop), above tree biomass and total tree biomass had highest positive correlation under agroforestry system. The vegetation carbon pool also have higher positive association with total biomass (tree + crop) also (0.885) during first year and pooled mean (0.825) whereas, above tree biomass and total tree biomass (0.854 and 0.854) showed higher positive correlation under wheat and eucalyptus based agroforestry system. The mean of two year revealed that linear increase in CO_2 equivalent C stock was predicted with wheat biomass, weed biomass, fresh bole wt, above tree biomass, total tree biomass, total biomass (tree + crop) and vegetation carbon pool t ha^{-1}. The increase in CO_2 equivalent C stock could be predicted by 1.689, 1.299, 0.907, 0.997, 0.791, 1.523 and 3.311 t ha^{-1} under wheat- *Eucalyptus tereticornis* based agroforestry system.

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