FINAL PROJECT REPORT

i.	Project code and title	**PPS 3559:** Testing of carbon capturing potential of mulberry in different locations
ii.	Name of the Project investigators (including coordinator in case of collaborative projects)	Coordinator: D. Chakravarty (from 01.01.2018), M. Chaudhuri (form 09.09.2016 to 31.12.2017), R. Kar (upto 08.09.2016) Investigators: R. Kar, S. Chatterjee (upto 30.11.2016), S. K. Misro, G. S. Singh and S. N. Gogoi
iii.	Duration (Date of Start) – (Date of Completion)	April, 2015 - March, 2018
iv.	Name (s) of the Institute (s) and Address	Central Sericultural Research and Training Institute, Berhampore-742 101, Murshidabad, West Bengal

v. A list of Objectives / Goals (clearly indicating how far they have been achieved; indicating the difficulties / reasons in case of achievement gap)

To assess carbon capturing potential of mulberry growing under varying eco-geographic conditions

Achievement is in commensuration with the objectives highlighting the following:

- Carbon capturing potential of mulberry growing under varying eco-geographic conditions, namely, Eastern Himalayas, per-humid eco-region with brown and red hill soils of Kalimpong, Eastern Ghat, hot sub-humid eco-region with red and laterite soils of Koraput, Eastern (Chhotanagpur) Plateau, hot sub-humid eco-region with red and laterite soils of Ranchi and Assam plain, hot sub-humid eco-region with alluvium derived soils of Jorhat, has been assessed.
- Carbon credit due to alteration of farming practice in mulberry growing under different eco-geographic conditions as mentioned above has also been enumerated.

vi. Introduction

The finding of the project, PPS 3452, entitled "Terrestrial carbon sequestration for sustained high productivity of quality mulberry" concluded at the farm of CSR&TI, Berhampore (WB) under irrigated alluvial soil condition has highlighted the performance of altered farming practice, 'moderate tillage with grass cover', in terms of carbon capturing potential (CCP) estimating to 6.90×10^{-9} Gt ha^{-1} $year^{-1}$ in comparison to the existing farming practice (intensive tillage without grass cover) recording CCP of 6.54×10^{-9} Gt ha^{-1} $year^{-1}$.

Mulberry is being grown in different eco-geographic regions of Eastern and North-Eastern India (Bose and Kar, 2010). Regional research centers under CSR&TI,

Berhampore (WB) situated at Kalimpong, Koraput, Ranchi and Jorhat were entrusted to take care of executing region specific R & D assignments.

Considering the current agenda of Global Warming, it is proposed to assess carbon sequestration potential of mulberry growing in other regions also and for that purpose, the altered farming practice diagnosed competent so far, had been tried at regional level. The diagnosed altered farming practice had been tested against existing farming practices of different regions for comparison.

vii. Methodology Adopted

- The field experimentation had been executed at farm level of each of the four units, namely, Kalimpong, Koraput, Ranchi and Jorhat
- Each farm spared a land of 0.1 bigha (0.033 acre) each for existing farming practice and altered farming practice
- Once deep digging and rest shallow (single surface) diggings along with grass cover had been considered under altered farming practice followed by incorporation of the grass cover with the soil
- Under existing farming practice, all the diggings were deep and there was regular weeding, but no incorporation of grass with soil
- Crop wise recording of leaf productivity and collection of leaf samples for estimation of carbon
- Recording of shoot productivity and collection of shoot samples for estimation of carbon matching with the pruning schedule
- Estimation of moisture% of leaf and shoot samples (at $70^{o}C$)
- Ignition of oven-dried (at $70^{o}C$) leaf and shoot samples at $550^{o}C$ for 6 h in a muffle furnace to determine the carbon content (Nath and Das, 2011)
- Computation of carbon capturing potential of mulberry on the basis of dry weights of leaf and shoot

viii. Observations / Results duly indicating the output in terms of adding to knowledge; know-how / new packages / practices / processes / products / innovations developed and their utility and advantages

Productivity and CCP of mulberry

Carbon sequestration depends upon biomass production capacity, which, in turn, depends upon interaction between edaphic, climate and topographic factors of an area. Hence results obtained at one place may not be applicable to another. Therefore, region-based potential of different land uses needs to be worked out.

Development of high yielding mulberry varieties is the basic need of sericulture industry for enhancing the rearing capacity of silkworm. Besides higher productivity, the high yielding mulberry varieties are providing huge biomass for carbon mitigation by photosynthetic capture and thus, prove to be an effective agent for offsetting carbon emissions. But, evaluation of those mulberry varieties in terms of carbon sequestration potential in varying conditions has not been paid serious attention hitherto. Considering the current agenda of Global Warming, it was proposed to assess carbon capturing potential of mulberry growing in different regions and for that purpose, the altered

farming practice as 'moderate tillage with grass cover' diagnosed competent so far, had been tried at regional level. The diagnosed altered farming practice had been tested against existing farming practices (intensive tillage without grass cover) of different regions for comparison.

In view of the above, information pertaining to productivity and CCP of mulberry grown under existing (intensive tillage without grass cover) as well as altered farming practice (moderate tillage with grass cover) in different test centers have been generated and furnished in the following tables:

Table 1: Yield and carbon capturing potential of mulberry growing under two different farming practices at Kalimpong

Season	Sample	Leaf/ shoot yield (kg ha^{-1})		Carbon capturing potential (x 10^{-12} Gt ha^{-1})	
		Altered farming practice	Existing farming practice	Altered farming practice	Existing farming practice
August, 2015	Leaf	6320	5880	792	669
December, 2015	Shoot	6075	5850	941	847
April, 2016	Leaf	5760	5020	653	554
June, 2016	Shoot	6480	5980	920	820
August, 2016	Leaf	5840	5320	710	609
December, 2016	Shoot	6030	5760	886	813
April, 2017	Leaf	5880	5440	678	608
June, 2017	Shoot	6130	5870	869	794
December, 2017	Shoot	5980	5700	873	804

Mulberry growing in Eastern Himalayas, per-humid eco-region with brown and red hill soils of Kalimpong (table-1) registered significant effect of alteration of farming practice on CCP [t-stat (leaf) 2.565*; t-stat (shoot) 4.932**]. Compilation of data revealed that mulberry growing under moderate tillage with grass cover (altered farming practice) can capture an average of 3.21x 10^{-9} Gt carbon annually from one hectare of land while mulberry growing under existing farming practice (intensive tillage without grass cover) can capture 2.85x 10^{-9} Gt carbon annually from the same area of land. Thus, the former registered an annual carbon credit of 0.36x 10^{-9} Gt ha^{-1} over the existing farming practice.

Table-2 furnishes below data pertaining to CCP of mulberry growing in Eastern Ghat, hot sub-humid eco-region with red and laterite soils of Koraput and the same exhibited that altered farming practice had an edge over existing farming practice in terms of CCP (t-stat NS). Compilation of data revealed that mulberry growing under moderate tillage with grass cover (altered farming practice) can capture an average of 2.31x 10^{-9} Gt carbon annually from one hectare of land while mulberry growing under existing farming practice (intensive tillage without grass cover) can capture 2.10x 10^{-9} Gt carbon annually from same area of land. Thus, the former registered an annual carbon credit of 0.21x 10^{-9} Gt ha^{-1} over the existing farming practice.

Table 2: Yield and carbon capturing potential of mulberry growing under two different farming practices at Koraput

Season	Sample	Leaf/ shoot yield (kg ha^{-1})		Carbon capturing potential (x 10^{-12} Gt ha^{-1})	
		Altered farming practice	Existing farming practice	Altered farming practice	Existing farming practice
August, 2015	Leaf	4315	4231	484	453
October, 2015	Leaf	3571	3492	500	471
December, 2015	Shoot	1357	1295	201	183
March, 2016	Leaf	2580	2450	310	282
June, 2016	Shoot	4617	4444	647	597
August, 2016	Leaf	4346	4229	465	434
October, 2016	Leaf	3622	3486	431	398
December, 2016	Shoot	4069	3812	537	497
March, 2017	Leaf	2641	2053	285	255
June, 2017	Shoot	4593	4469	652	603
August, 2017	Leaf	4596	4317	516	449
October, 2017	Leaf	3638	3497	495	448
December, 2017	Shoot	3960	3570	552	466
March, 2018	Leaf	2366	2290	323	299

Table 3: Yield and carbon capturing potential of mulberry growing under two different farming practices at Ranchi

Season	Sample	Leaf/ shoot yield (kg ha^{-1})		Carbon capturing potential (x 10^{-12} Gt ha^{-1})	
		Altered farming practice	Existing farming practice	Altered farming practice	Existing farming practice
August, 2015	Leaf	4582	4452	516	484
October, 2015	Leaf	4231	4014	552	495
December, 2015	Shoot	2061	1986	304	278
March, 2016	Leaf	3198	3127	430	404
June, 2016	Shoot	4725	4684	626	610
August, 2016	Leaf	4673	4547	541	515
October, 2016	Leaf	4530	4359	538	499
December, 2016	Shoot	2141	2215	274	277
March, 2017	Leaf	3045	2985	416	396
June, 2017	Shoot	4796	4695	652	613
August, 2017	Leaf	4693	4541	559	517
October, 2017	Leaf	4538	4370	528	475
December, 2017	Shoot	2246	2154	302	271
March, 2018	Leaf	3074	2992	374	345

Mulberry growing in Eastern (Chhotanagpur) Plateau, hot sub-humid eco-region with red and laterite soils of Ranchi (table-3) exhibited similar trend as that of Koraput. Compilation of data revealed that mulberry growing under moderate tillage with grass cover (altered farming practice) can capture an average of 2.35 x 10^{-9} Gt carbon annually from one hectare of land while mulberry growing under existing farming practice (intensive tillage without grass cover) can capture 2.20 x 10^{-9} Gt carbon annually from same area of land. Thus, the former registered an annual carbon credit of 0.15 x 10^{-9} Gt ha^{-1} over the existing farming practice.

The non significant effect of altered farming practice over existing farming practice in terms of CCP in Koraput and Ranchi might be due to poor growth of grasses (weeds) under red and laterite soils receiving comparatively lesser precipitation, incorporation of which with soil imparted lesser effect in improving the ambience of soil in terms of organics.

Table 4: Yield and carbon capturing potential of mulberry growing under two different farming practices at Jorhat

Season	Sample	Leaf/ shoot yield (kg ha^{-1})		Carbon capturing potential (x 10^{-12} Gt ha^{-1})	
		Altered farming practice	Existing farming practice	Altered farming practice	Existing farming practice
October, 2015	Leaf	4390	4200	579	513
December, 2015	Shoot	2160	1840	337	275
April, 2016	Leaf	5886	5600	647	587
June, 2016	Shoot	4865	4596	750	676
June, 2016	Leaf	5943	5657	663	580
October, 2016	Leaf	5675	5429	672	580
December, 2016	Shoot	4880	4641	721	650
April, 2017	Leaf	5257	5114	599	545
June, 2017	Shoot	4665	4525	683	650
June, 2017	Leaf	5268	5115	577	560
October, 2017	Leaf	4829	4629	565	511
December, 2017	Shoot	4480	4281	695	626

On the other hand, mulberry growing in Assam plain, hot sub-humid eco-region with alluvium derived soils of Jorhat (table-4) registered significant effect of alteration of farming practice on CCP of leaf [t-stat (leaf) 2.927*], but not on shoot [t-stat (shoot) NS]. Compilation of data revealed that mulberry growing under moderate tillage with grass cover (altered farming practice) can capture an average of 3.12 x 10^{-9} Gt carbon annually from one hectare of land while mulberry growing under existing farming practice (intensive tillage without grass cover) can capture 2.81 x 10^{-9} Gt carbon annually from same area of land. Thus, the former registered an annual carbon credit of 0.31 x 10^{-9} Gt ha^{-1} over the existing farming practice.

Table 5. Effect of different treatments on leaf yield at different locations:

Particulars	Altered farming practice	Existing farming practice	Mean Leaf yield (kg ha^{-1})
Kalimpong	5,950.00	5,415.00	5,682.50
Koraput	3,519.44	3,338.33	3,428.89
Ranchi	4,062.67	3,931.89	3,997.28
Jorhat	5,321.14	5,106.29	5,213.71
Mean leaf yield (kg ha^{-1})	4,713.31	4,447.88	
Factors	**C.D.**	**SE(d)**	**SE(m)**
Location (L)	355.413	176.947	125.12
Treatment (T)	251.315	125.12	88.473
Interaction (L X T)	NS	250.24	176.947

Table 6. Effect of different treatments on carbon capturing potential (CCP) of leaf samples at different locations:

Particulars	Altered farming practice	Existing farming practice	Mean CCP (x 10^{-12} Gt ha^{-1})
Kalimpong	708.250	610.000	659.125
Koraput	423.222	387.667	405.445
Ranchi	494.889	458.889	476.889
Jorhat	614.571	553.714	584.143
Mean CCP (x 10^{-12} Gt ha^{-1})	560.233	502.568	
Factors	**C.D.**	**SE(d)**	**SE(m)**
Location (L)	33.945	16.9	11.95
Treatment (T)	24.003	11.95	8.45
Interaction (L X T)	NS	23.9	16.9

Table 7. Effect of different treatments on shoot yield at different locations:

Particulars	Altered farming practice	Existing farming practice	Mean shoot yield (kg ha^{-1})
Kalimpong	6,139.00	5,832.00	5,985.50
Koraput	3,719.20	3,518.00	3,618.60
Ranchi	3,193.80	3,146.80	3,170.30
Jorhat	4,210.00	3,976.60	4,093.30
Mean shoot yield (kg ha^{-1})	4,315.50	4,118.35	
Factors	**C.D.**	**SE(d)**	**SE(m)**
Location (L)	694.205	337.16	238.408
Treatment (T)	NS	238.408	168.58
Interaction (L X T)	NS	476.816	337.16

Table 8. Effect of different treatments on carbon capturing potential (CCP) of shoot samples at different locations:

Particulars	Altered farming practice	Existing farming practice	Mean CCP ($x\ 10^{-12}$ Gt ha^{-1})
Kalimpong	897.8	815.6	856.7
Koraput	517.8	469.2	493.5
Ranchi	431.6	409.8	420.7
Jorhat	637.2	575.4	606.3
Mean CCP ($x\ 10^{-12}$ Gt ha^{-1})	621.1	567.5	
Factors	**C.D.**	**SE(d)**	**SE(m)**
Location (L)	103.079	50.063	35.4
Treatment (T)	NS	35.4	25.032
Interaction (L X T)	NS	70.8	50.063

Pooled analysis with 'common error' for better inference of location effect (table 5-8) showed significant effect of different locations on leaf yield, shoot yield and carbon capturing potential of leaf and shoot samples. Significant effects of different treatments were also observed on leaf yield and carbon capturing potential of leaf. However, effect of the treatments on shoot yield and carbon capturing potential of shoot were not significant.

x. Inference / Recommendations

As per assigned target of the study, carbon capturing potential of mulberry growing under varying eco-geographic conditions as discussed above, has been assessed. Information has also been generated on carbon credit due to alteration of farming practice in mulberry growing under different eco-geographic conditions. The order of annual carbon credit ($x\ 10^{-9}$ Gt ha^{-1}) in different locations is as follows:

Kalimpong (0.36) > Jorhat (0.31) > Koraput (0.21) > Ranchi (0.15)

The altered farming practice, "moderate tillage with grass cover" promises to enhance carbon capturing potential of mulberry substantially on long term basis through continuous improvement of soil organic ambience. The protocol is efficient enough to achieve the target of offsetting carbon emission from the atmosphere at an enhanced rate and to store the same subsequently in terrestrial system for further use. The approach matches the current Global agenda for terrestrial sequestration of carbon and promises to act as an agent to save the Globe from warming.

xi. Applications made for patenting / commercialization if any

Not applicable

xii. References

Bose, P. C. & Kar, R. (2010) Soil characteristics and nutritional management of mulberry in Eastern and North-Eastern India, *CSR & TI, Berhampore (WB)*, pp.14-15.

Nath, A. J. & Das, A. K. (2011) Carbon storage & sequestration in bamboo-based smallholder home gardens of Barak valley, Assam. *Curr. Sci.*, **100**, 229-233.

xiii. Papers Published Nil

xiv. Summary

The study under the project aims at assessing CCP of mulberry growing under varying eco-geographic conditions. Based on the finding of the project PPS 3452, concluded at CSR&TI, Berhampore, performance of altered (moderate tillage with grass cover) and existing (intensive tillage without grass cover) farming practices has been investigated in the locations of other regions in terms of CCP and information has also been generated on carbon credit due to alteration of farming practice in mulberry growing under diverse eco-geographic conditions. The order of annual carbon credit (x 10^{-9} Gt ha^{-1}) in different locations is as follows:

Kalimpong (0.36) > Jorhat (0.31) > Koraput (0.21) > Ranchi (0.15)

The altered farming practice, "moderate tillage with grass cover" promises to enhance carbon capturing potential of mulberry substantially on long term basis through continuous improvement of soil organic ambience. Thus, the protocol is efficient enough to achieve the target of offsetting carbon emission from the atmosphere at an enhanced rate and to store the same subsequently in terrestrial system for further use. The approach matches the current Global agenda for terrestrial sequestration of carbon and promises to act as an agent to save the Globe from warming.

xv	Budget Utilized etc.	Rs. 1.16 lakh utilized out of Rs. 2.58 lakh Difference is due to non-procurement of non-recurring items by Ranchi and Jorhat; leaf and shoot samples of Ranchi and Jorhat have been analyzed at CSR&TI, Berhampore (WB) for estimation of carbon content.

Signature of the Principal Investigator: (Dr. R. Kar)

Signature of the Co-investigator(s): NIL (Dr. S N Goga) (S.K. Mishra)

Signature (with comments, if any) of Head of ~~Division~~ Coordinator: Dr. G. S. Singh

See next Page

Signature (with comments, if any) of Director: 28.8.18

निदेशक / Director (I/c)
केन्द्रीय रेशम उत्पादन अनुसंधान एवं प्रशिक्षण संस्थान
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RAC Recommendations:

Suggestion of 48th RAC meeting dt.24.07.2018	Action taken
The project has been concluded as per the milestones. However, the following suggestions were made for future plan of work: • The standard unit for carbon capturing potential should be expressed in giga tonnes per hectare. • Pooled analysis may be considered with 'common error' for better inference of location effect. • Carbon sequestration at root level (below ground) can be estimated, if possible.	• Complied and expressed unit for carbon capturing potential in giga tonnes (Gt) per hectare • Complied and incorporated pooled analysis results in this report. • As per approved mile stone of the project carbon capturing potential of leaf and shoot samples of mulberry has been estimated in different seasons and the project has been concluded during march 2018. Therefore, separate experimentation can be taken up in future for estimation of carbon capturing potential of mulberry root. And for the same mulberry plant has to be uprooted for collection of root sample.

Directors comment:

As per assigned objective of the study, information has been generated on carbon capturing potential of mulberry growing under varying eco-geographic conditions, namely, Eastern Himalayas, per-humid eco-region with brown and red hill soils of Kalimpong; Eastern Ghat, hot sub-humid eco-region with red and laterite soils of Koraput; Eastern (Chhotanagpur) Plateau, hot sub-humid eco-region with red and laterite soils of Ranchi and Assam plain, hot sub-humid eco-region with alluvium derived soils of Jorhat. Information generated from the study has well bearing with atmospheric purification through mulberry cultivation in terms of offsetting carbon emission from the atmosphere and the same may be linked up with the similar study formulated and executed in future for environmental cause.

28-8-18

DIRECTOR I/c

CSR&TI, BERHAMPORE

(Office seal)

निदेशक / Director (I/C)

केन्द्रीय रेशम उत्पादन अनुसंधान एवं प्रशिक्षण संस्थान
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