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ICAR

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ANNUAL REPORT
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भा.कृ.अनु.प.-केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी

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PREFACE

It is my pleasure to present the Annual Report (2019) of ICAR-Central Agroforestry Research Institute, Jhansi. The Institute conducts basic, strategic and applied agroforestry research through experiments at on farmers field and on station. Agroforestry has immense potential to increase sustainability, livelihood of farmers in agriculture, while optimizing its productivity and mitigating climate change impact. Agroforestry research outputs based on the objectives and activities for 2019 under 15 institutionally funded and 11 externally funded projects were planned in accordance with the recommendations of Research Advisory Committee (RAC) and other advisory bodies.

The Institute is working on three aspects under NICRA project *viz.*, assessment of carbon sequestration potential of agroforestry systems in different agro-climatic regions through simulation model (CO2Fix model), mapping of agroforestry area using GIS and Remote Sensing technique and study on thermotolerance. The assessment of carbon sequestration potential (CSP) has been completed in 57 districts from 17 states. The carbon sequestration potential (CSP) of agroforestry systems is 0.35 t t C/ha/year. The area under agroforestry in 12 agro-climatic zone (23.25 million ha) in the country, the total carbon stock will be 8.13 million tones and CO_2 equivalent C will be 29.83 million tones. In this way the agroforestry can offset 22.41 t CO_2 from total CO_2 Equivalent GHG emission (1831.64 million tonnes). In other word, contribution of agroforestry to offset total GHG emission is 1.63%.

Mapping of agroforestry area in 12 agro-climatic zone has already been completed and the total area under agroforestry in these zones was estimated to be 23.25 million ha of total geographical area (267.66 million ha).

During this year ICAR-CAFRI has initiated the upscaling of Prasai-Sindh watershed model in seven district of Bundelkhand U.P. in a consortium mode with ICRISAT, Hyderabad along with other consortium partners under the doubling farmers Income Project (KISAN MITrA).

Most significantly, ICAR-CAFRI initiated agroforestry interventions in all the seven districts at pilot sites. Nearly 85,000 saplings of teak, lime, guava including other fruit species and *Acacia senegal* have been planted. The quality tree saplings were procured from various forest department nurseries and also from Institute. Nearly 2000 local *ber* trees in 228 farmers' fields were rejuvenated through top working.

The consortium has undertaken number of capacity building programs for different stakeholders such as farmers, masons, NGO staff on soil fertility management, mechanization, productivity enhancement, construction of rain water harvesting structures, agroforestry, etc. Moreover, number of stakeholder workshops, review meeting, exposure visits were organized at ICAR-CAFRI, Parasai-Sindh watershed and pilot sites. Till date, more than 11,000 farmers/families have been directly benefited from this integrated system approach of DFI Bundelkhand initiative; never the less, many more families received indirect benefits.

During this year, under ICAR-ICRAF work plan, the studies were conducted in Bolangir and Nuapada districts of Odisha to enhance groundwater recharge through suitable structures to facilitate agroforestry landuse, improve and optimize crop and livestock productivity to check the migration and develop model site of learning in selected patches in three villages of both the districts.

About 25,000 m^3 rainwater harvesting capacity was created at Tara village in Bolangir district and about 7000 m^3 in Boirbhadi village in Nuapada district.

The Institute organized number of Farmers' activities like Farmer's Workshop, Training programmes and exhibitions for transfer of agroforestry technologies and to increase the awareness for speedy adoption of agroforestry. The plantation drive was carried out by scientists of ICAR-CAFRI Jhansi in the selected MGMG villages and total 5350 plants were distributed to the farmers of nearby villages of Jhansi.

ICAR-CAFRI, Indian Society of Agroforestry and ICRAF, South Asia Office, New Delhi organized an International Training Program on "Agroforestry" for Middle level Policy Makers from Asian and African countries at ICAR-CAFRI. The Training was jointly organized by National Institute of Agricultural Extension Management (MANAGE) in collaboration with Indian Council of Agriculture Research (ICAR); ICAR- Central Agroforestry Research Institute, Jhansi; Forest Collage & Research Institute, Mettupalayam, Tamil Nadu and World Agroforestry (International Centre for Agroforestry Research-ICRAF) centre.

I express my gratitude to Dr. Trilochan Mohapatra, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi for his constant guidance, encouragement and overwhelming support. I am very much pleased to thank Dr. S K Chaudhari, Deputy Director General (NRM), ICAR, New Delhi for his constant direction and motivation. I owe special appreciation to Dr. S Bhaskar, ADG (Agron. AF/CC) and all the staff members of NRM Division for continuous support. I acknowledge the efforts made by the PME Cell and Editors in compiling and timely publication of the report. I am thankful to the Director, ICAR-IGFRI, Jhansi for continuous support in sharing the infrastructure and facilities from time to time.

July, 2020

(R K Tewari)
Director (A)

कार्यकारी सारांश

भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान को भारतीय कृषि अनुसंधान परिषद की एक इकाई के रूप में वर्ष 1988 के दौरान झाँसी में स्थापित किया गया। संस्थान द्वारा पिछले 32 वर्षों में विभिन्न कार्यक्रमों के अन्तर्गत अनुसंधान कार्य किये जा रहे हैं। संस्थान में किये जा रहे अनुसंधान का कार्यकारी सारांश निम्नलिखित है:

बेर आधारित कृषि–उद्यानिकी पद्धति में बेर के विभिन्न गुणों (पौधे की वृद्धि, छंटाई और फल) ने छत्रक का प्रसार, गुठली का वजन, गूदा : गुठली के अनुपात और कुल घुलनशील शर्करा को छोड़कर काफी प्रभावित किया गया। अध्ययन से पता चला है कि ज्यादातर उपचारों में टी$_8$ (बेर के साथ 75% आरडीएफ + ट्राइकोडर्मा + उर्द – जौ) ने अपनी श्रेष्ठता दिखाई है,लेकिन यह उपचार टी$_6$ (बेर के साथ 75% आरडीएफ + वैम + उर्द– जौ) या टी$_2$ (बेर के साथ 100% आरडीएफ + उर्द – जौ) के साथ सममूल्य पर था। प्रणाली के तहत, रबी में जौ की फसल को दिसम्बर, 2018 के दौरान बोया गया तथा अप्रैल, 2019 के दौरान काटा गया और अवलोकनों से पता चला कि उपचार टी$_{10}$ (शुद्ध फसल) और टी$_6$ (बेर के साथ 75% आरडीएफ + वैम + उर्द – जौ) ने 2498 और 2482 किलोग्राम/है, की उच्चतम दाना उपज दर्ज की जोकि अन्य उपचारों की तुलना में काफी अधिक थी। उर्द को खरीफ, 2019 में उगाया गया और अवलोकन से पता चला कि उपचार टी$_{10}$ (शुद्ध फसल) और टी$_6$ (बेर के साथ 75% आरडीएफ + वैम + उर्द – जौ) में क्रमशः 278 और 269 किलोग्राम/है की दाना उपज दर्ज की गई जोकि अन्य उपचारों की तुलना में काफी अधिक थी।

अनार के पौधों के बीच में नींबूघास (प्रजाति कृष्णा) को 50 x 40 सेमी के अंतर पर लगाकर योजना बनाई और क्रियान्वित की गई। जुलाई–अगस्त, 2018 के दौरान घास–गुच्छों के आकार में वृद्धि के कारण, नींबू घास के घास–गुच्छों के बीच से एक घास–गुच्छें को हटाकर घास–गुच्छों के बीच की दूरी को 100x80 सेमी में बदल दिया गया। अनार में वृद्धि और फलों की पैदावार, नींबूघास की पत्तियों और तेल की पैदावार में वृद्धि के आंकड़े एकत्रित किये गये। अनार में, ऊँचाई 2.32 मीटर (टी$_4$वी$_2$– भगवा के साथ निर्धारित रासायनिक खाद की दर) से 3.49 मीटर (टी$_2$वी$_1$– गणेश के साथ 30 किलोग्राम गोबर की खाद), स्कंध व्यास 5.55 सेमी (टी$_2$ वी$_2$– भगवा के साथ 30 किलो गोबर की खाद) से 7.84 सेमी (टी$_1$वी$_1$–गणेश के साथ 30 किलो वर्मीकम्पोस्ट) तक अंकित किया गया। पूर्व–पश्चिम में 1.72 मीटर (टी$_4$वी$_2$) से 2.85 मी (टी$_2$वी$_1$) और उत्तर–दक्षिण में 1.52 मीटर (टी$_4$वी$_2$) से लेकर 2.63 मीटर (टी$_4$वी$_1$) तक फैलाव अंकित किया गया। हालाँकि, फल की पैदावार 4.40 (टी$_3$वी$_2$–भगवा के साथ 30 किलो वर्मीकम्पोस्ट + 30 किग्रा गोबर की खाद) से 6.61 (टी$_4$ वी$_1$– गणेश के साथ निर्धारित रासायनिक खाद की दर) किग्रा/पौध थी। नींबूघास की दो बार कटाई करने से संचयी उपज 12.76 (टी$_2$वी$_1$) से 25 .90 (टी$_5$) टन/है दर्ज की गयी और ताजे वजन के आधार पर हरी पत्तियों से तेल की उपज 76.09 (टी$_2$वी$_1$) से 265.53 (टी$_5$–शुद्ध नींबूघास) किलो तेल/है तक प्राप्त हुयी।

लघु चक्रीय वृक्ष आधारित कृषिवानिकी प्रणाली का संरचनात्मक और कार्यात्मक विश्लेषण'' नामक परियोजना वर्ष 2016 में शुरू की गई थी। इस परियोजना के तहत, तीन तेजी से बढ़नें वाले वृक्ष प्रजातियों जैसे *एन्थोसेफालस कदंबा, मेलिया डूबिया* और *ल्युसिना ल्यूकोसेफेला* को दो स्पेसिंग 4 x 5 मीटर और 8 x 2.5 मीटर में लगाया गया है। इस परियोजना में प्रत्येक स्पेसिंग के अंतर्गत सात उपचार जोकि टी 1–एंथोसेफालस कदंबा + फसल, टी 2 – *मेलिया डूबिया* + फसल, टी 3 –*ल्युसिना ल्यूकोसेफेला* + फसल, टी 4 –*एंथोसेफालस कदंबा* (शुद्ध वृक्षारोपण), टी 5 –*मेलिया डूबिया* (शुद्ध वृक्षारोपण) टी 6 –*ल्युसिना ल्यूकोसेफेला* (शुद्ध वृक्षारोपण) और टी 7 –शुद्ध फसल आरबीडी के तहत तीन प्रतिकृति के साथ शुद्ध फसल (खरीफ/रबी) शामिल हैं। इस परियोजना में उर्द –गेहूँ की फसल चक्र लिया जा रहा है। परियोजना का मुख्य उद्देश्य वृक्षों के घटकों में वृद्धि, बायोमास और कार्बन अनुक्रमीकरण प्रवृत्तियों का आंकलन करना, वृक्षों का फसल और फसल उत्पादकता पर प्रभाव का मूल्यांकन करना और ईंधन की लकड़ी, लुगदी और कागज उद्योगों के संबंध में लकड़ी के गुणों का अध्ययन करना है। प्रत्येक भूखंड में प्रत्येक वृक्ष की प्रजातियों के सोलह वृक्ष लगाए गए हैं (16 x 20 मीटर = 320 मीटर^2)। यद्यपि विनाशकारी विधि के माध्यम से वृक्षों में कार्बन अनुक्रम की गणना के लिए वृक्षों की अतिरिक्त पंक्तियों को लगाया गया है।

हर साल, वृक्ष के घटकों में बायोमास और कार्बन स्टॉक की गणना के लिए 4 x 5 मीटर स्पेसिंग से प्रत्येक प्रजाति के तीन वृक्षों की कटाई की जा रही है। वृक्षों की अंतिम कटाई और लकड़ी के गुणों का अध्ययन करने के लिए आठ साल की रोटेशन उम्र तय की गई है। इन तेजी से बढ़ती वृक्ष प्रजातियों में, जब कृषिवानिकी में उगाए गए *एम. डूबिया* ने अधिकतम ऊँचाई (10.48 मीटर) और डीबीएच (151.22 मिमी) प्राप्त की जबकि शुद्ध वृक्षारोपण में 10.42 मीटर और 164.00 मिमी, 4 x 5 मीटर की दूरी पर रोपित वृक्षों से प्राप्त की। इसी तरह, *एम. डूबिया* में अधिकतम सूखा बायोमास (102.56 किलोग्राम/वृक्ष) और कार्बन स्टॉक (51.28 किलोग्राम/वृक्ष) भी दर्ज किया गया। जमीन के ऊपर के हिस्सों और जमीन के नीचे के हिस्सों का सूखा बायोमास में हिस्सा क्रमशः 82.41 प्रतिशत और 17.59 प्रतिशत था। जड़ों के अध्ययन से पता चला है कि जड़ प्रणाली सभी वृक्ष प्रजातियों में एक समान थी। *ए. कदम्बा, एम. डूबिया* और *एल. ल्यूकोसेफेला* जिसमें अधिकतम जड़ *एम. डूबिया* (4.80 मीटर पूर्व–पश्चिम : 4.0 मीटर उत्तर–दक्षिण) में फैली हुई थी। इन वृक्ष प्रजातियों में उथली प्राथमिक जड़ प्रणाली देखी गई थी। *ए. कदम्बा* में मूसला जड़ 248 सेमी लम्बी *एम. डूबिया* में 211 सेमी और *एल. ल्यूकोसेफेला* में 208 सेमी लम्बी थी। *ए. कदम्बा, एम. डूबिया* और *एल. ल्यूकोसेफला* में मूसला जड़ क्रमशः 15–25 सेमी, 22–25 सेमी और 15–20 सेमी मिट्टी में ऊर्ध्वाधर रूप से बढ़ती हुयी पायी गयी। रूट सिस्टम *ए. कदम्बा* में मध्यम फैला हुआ, *एम. डूबिया* में व्यापक और सघन और *एल. ल्यूकोसेफेला* में विसरित प्रकार पाया गया। उच्च क्रम की जड़ों ने सभी प्रजातियों में संकीर्ण जड़ कोण दिखाए। सबसे कम फसल की पैदावार वृक्ष की पंक्ति के पास यानी वृक्ष की पंक्ति से 1 मीटर दूरी पर देखी गई थी ।

सतत् भूमि उपयोग एवं बेहतर उत्पादकता के लिए कृषिवानिकी आधारित संरक्षण कृषि'' परियोजना को जुलाई, 2014 में 3 प्रयोगों के साथ शुरू किया गया था जैसे कि बेल आधारित कृषिवानिकी, सागौन आधारित कृषिवानिकी तथा बेल एवं सागौन आधारित कृषिवानिकी, 04 मुख्य भूखण्ड उपचार और 03 उपभूखण्ड उपचार के साथ शामिल किये गये थे। ये भूखण्ड उपचार जैसे कि न्यूनतम जुताई उर्द–सरसों (सी एस–1), न्यूनतम जूताई मूँग–जौ (सी एस–2), पारम्परिक जुताई उर्द–सरसों (सी एस–1), पारम्परिक जुताई मूँग–जौ (सी एस–2) थे। उपभूखण्ड उपचार जैसे कि फसल अवशेष संयोजन, बिना फसल अवशेष संयोजन एवं सूबबूल अवशेष संयोजन लगाये गये।

बेल आधारित संरक्षित कृषि (सीए) प्रणाली में सबसे अधिक बीज उपज (546.0 किग्रा/है), फसल उपचार में दर्ज की गई, उसके बाद सूबबूल अवशेष उपचार में (529.5 किग्रा/है) दर्ज की गई। जौ के अनाज की पैदावार 1218.2 किग्रा/है (न्यूनतम जुताई) से लेकर 1237.2 किग्रा/है (पारम्परिक जुताई) तक थी, हालांकि गैर–महत्वपूर्ण थी। फसल अवशेषों के डालने से जौ की बीज उपज में वृद्धि हुई जोकि बिना किसी अवशेष उपचार से काफी ज्यादा थी। खरीफ मौसम (2019) के दौरान न्यूनतम जुताई (एमटी) में चने के बीज की पैदावार 154.6 किग्रा/है दर्ज की गई थी, जो कि पारम्परिक जुताई (सीटी) में 162.7 किग्रा/है से थोड़ी कम थी, हालांकि अन्तर गैर–महत्वपूर्ण था। अवशेषों के डालने से चने के बीज की उपज में काफी वृद्धि हुई। इसकी पैदावार 119.0 किग्रा/है (कोई अवशेष नहीं) से 142.0 किग्रा/है (फसल अवशेष) दर्ज की गई। मूँग के बीज की पैदावार न्यूनतम जुताई (एमटी प्लाट) में 154.6 किग्रा/है से लेकर पारम्परिक जुताई (सीटी प्लाट) में 162.7 किग्रा/है तक दर्ज की गई। सागौन आधारित संरक्षण कृषि प्रणाली और बेल एवं सागौन आधारित कृषि प्रणाली में विभिन्न उपचारों जैसे कि जुताई उपचार, अवशेष प्रतिधारण/सूबबूल डालने में, कुल मिलाकर समान प्रवृत्ति देखी गयी।

बेल और सागौन के विकास मानकों (वृक्षोच्च व्यास और ऊँचाई) पर अवलोकन से पता चलता है कि प्रणालियों के बीच दोनों वृक्ष प्रजातियों की ऊँचाई और वृक्षोच्च व्यास (डीबीएच) को लेकर कोई ज्यादा महत्वपूर्ण अन्तर नही था। बेल मे ऊँचाई 2.69 मीटर से लेकर 2.92 मीटर और वृक्षोच्च व्यास (डीबीएच) 58.81 मिमी से 67.16 मिमी दर्ज किये गये तथा सागौन में ये मानक क्रमशः 4.38 से 4.54 मीटर तथा 67.64 से 70.98 मिमी दर्ज किये गये। सभी तीनों कृषि प्रणालियों में मूँग–जौ उपचार के न्यूनतम जुताई आधारित संरक्षित कृषि में पारम्परिक जुताई आधारित संरक्षित कृषि की तुलना में कम जल प्रवाह के साथ–साथ, कम मृदा–क्षरण भी दर्ज किया गया।

बेल आधारित संरक्षित कृषि (सीए) प्रणाली में 0–15 सेमी मिट्टी की गहराई में जैविक कार्बन की मात्रा 0.367 प्रतिशत (पारम्परिक जुताई–चना–सरसों) से 0.424 प्रतिशत (न्यूनतम जुताई–मूँग–जौ) पाई गयी। सागौन आधारित संरक्षित कृषि प्रणाली के अंतर्गत 0.15 सेमी मिट्टी की परत में जैविक

कार्बन की मात्रा 0.463 प्रतिशत (पारम्परिक जुताई (सीटी) चना–सरसों) से 0.532 प्रतिशत (न्यूनतम जुताई (एमटी) चना–सरसों) आधारित फसल प्रणाली में दर्ज की गई थी। बेल एवं सागौन आधारित संरक्षित कृषि प्रणाली (सीए) में 0–15 सेमी गहराई तक जैविक कार्बन 0.440 प्रतिशत (पारम्परिक जुताई (सीए) मूँग–जौ) से लेकर 0.547 प्रतिशत (न्यूनतम जुताई (एमटी) चना–सरसों) तक दर्ज की गई। अलग–अलग कृषिवानिकी प्रणालियों में 30–45 सेमी परत तक लगभग समान परिणाम दर्ज किये गये। 45–90 सेमी के बीच की मिट्टी में जैविक कार्बन की मात्रा में कोई महत्वपूर्ण बदलाव नही दर्ज किये गये। यह स्पष्ट था कि सभी प्रणालियों में मूँग–जौ फसल प्रणाली के तहत न्यूनतम जुताई उपचार में 45 सेमी गहराई तक जैविक कार्बन काफी अधिक थी।

वर्ष 2019 में, समन्वित कृषि प्रणाली परियोजना के अन्तर्गत लगाये गये अमरूद और सहजन में प्रति पौधा क्रमशः 13.26 और 1.50 किग्रा पैदावार पायी गयी। इस परियोजना में सब्जी वाली मटर, गेहूँ, मक्का, भिण्डी, कददू, लौकी इत्यादि फसलों का सफलता पूर्वक उत्पादन लिया गया। वर्ष 2019 में फसलों तथा फलों के उत्पादन से कुल आमदनी 54180 रूपये हुयी।

सागौन तथा महोगनी के पौधों में तीन वर्ष पश्चात अधिकतम ऊँचाई तथा वृक्षोच्च व्यास टी$_7$ (सागौन + महोगनी + चारा + स्टैगर्ड कन्टूर ट्रेन्च) में पाया गया। हालांकि सागौन में बढ़वार तथा जीवित पौधों की संख्या महोगनी की अपेक्षा अधिक पायी गयी। दोनों चारों (*सेन्क्रस सिलियेरिस* तथा *स्टाइलोसैन्थस सियाब्राना*) के वृद्धिकारक तथा उत्पादन टी$_7$ (सागौन + महोगनी + चारा + स्टेगर्ड कन्टूर ट्रेन्च) में दूसरे उपचार की अपेक्षा अधिक पाया गया। मृदा नमी के लिए 15 दिनों के अन्तराल पर मृदा नमूने लिये गये जिसमें मार्च से लेकर जून महीने तक मृदा में औसत नमी 2 प्रतिशत से नीचे पायी गयी जोकि मानसून में 12 प्रतिशत (अधिकतम सागौन, महोगनी + चारा + स्टैगर्ड कन्टूर ट्रेन्च में) तक पहुँच गयी। परियोजना शुरू होने के तीसरे वर्ष के बाद पाया गया कि कन्टूर स्टेगर्ड ट्रेन्च और अर्ध चन्द्राकार थालों में क्रमशः 3.19 तथा 2.08 टन/है बही हुयी मिट्टी का जमाव हुआ। वर्ष 2019 में कुल पाँच बार जल बहाव की स्थिति उत्पन्न हुयी जिसमे सबसे कम जल बहाव टी$_7$ में उत्पन्न हुआ तथा सबसे ज्यादा जल का बहाव केवल महोगनी वाले प्लॉट में हुआ। जल के साथ मिट्टी का बहाव टी$_7$ में केवल 0.31 टन/है हुआ जबकि केवल महोगनी में 0.72 टन/है मिट्टी का बहाव हुआ।

अच्छी तरह से स्थापित कृषिवानिकी प्रणाली में सूक्ष्म जड़ों के क्षैतिज एवं ऊर्ध्वाधर वितरण के अध्ययन में पता चला है कि ऑवला एवं *हार्डविकिया बिन्नाटा* आधारित कृषिवानिकी प्रणाली में औसत सूक्ष्म जड़ों का बायोमास विभिन्न ऋतुओं में भिन्न पाया गया। ऑवला आधारित कृषिवानिकी प्रणाली में ज्यादातर सूक्ष्म जड़ बायेामास वृक्षों से 1.5 मी. की दूरी पर तथा 70 प्रतिशत हिस्सा (0–45) सेमी गहराई में दर्ज किया गया। वार्षिक सूक्ष्म जड़ उत्पादन दर सबसे अधिक वृक्षों से 1 मी. की दूरी पर मिली तथा टर्नओवर दर 1.63 प्रतिवर्ष (उच्चतम) 0.5 मी. दूरी से लेकर 1.03 प्रतिवर्ष (सबसे कम) 1.5 मी. की दूरी पर दर्ज की गई। जबकि *हार्डविकिया बिन्नाटा* आधारित कृषिवानिकी प्रणाली में 62 प्रतिशत सूक्ष्म जड़ बायोमास (0–45) सेमी गहराई में पाये गये। सूक्ष्म जड़ों की पर्याप्त दर चूँकि ऑवला आधारित कृषिवानिकी प्रणाली से कम थी पर उसकी टर्नओवर दर 1.21 प्रतिवर्ष (उच्चतम) 0.5 मी. दूरी से लेकर 0.54 प्रतिवर्ष (सबसे कम) 1.5 मी. दूरी पर दर्ज की गई।

सागौन के 34 काटे गए वृक्षों का वृक्षोच्च व्यास 14.94 से 38.42 सेमी और वृक्ष की ऊँचाई 11.2 से 19.00 मी. तक पायी गयी। सागौन की व्यावसायिक मात्रा का अनुमान चार पारंपरिक तरीकों अर्थात न्यूटन, ह्यूबर स्मालियन और छाल पर चौथाई व्यास के उपयोग से लगाया गया था, जिसमें क्रमशः 0.337, 0.332, 0.346, 0.264 मी.^{3}/वृक्ष की औसत मात्रा पायी गयी। सागौन के वृक्षों का औसत सूखा बायोमास और कार्बन स्टॉक क्रमशः 255.51 किलोग्राम/वृक्ष और 127.5 किलोग्राम/वृक्ष था। वृक्षोच्च व्यास केवल व्यावसायिक मात्रा का एक बहुत अच्छा भविष्यवक्ता पाया गया। सभी फिट फंक्शन में निर्धारण का गुणांक 0.92–0.95 भिन्न होता है, जबकि चौपमैन फंक्शन ने दूसरों के अध्ययन कार्यों पर बेहतर प्रदर्शन किया।

क्षेत्र की यात्रा के दौरान, किसानों के खेत में लगाए गए कई सागौन वृक्षारोपण की निगरानी की गई और असमान, टेढ़े, गाँठदार, सागौन के वृक्षों की रोगग्रस्त वृद्धि (झुकाव और पतलेपन) और सस्य कार्यों (निराई, सिंचाई और उर्वरक) की अनुपस्थिति के कारण महत्वपूर्ण अवलोकन प्रदान किए गए। वन विभाग, केवीके और निजी नर्सरी की सहायता से कुछ किसानों ने अच्छी तरह से प्रबंधित सागौन आधारित कृषि कृषिवानिकी हैं। लकड़ी डिपो और बढ़ई उद्योगों की यात्रा ने उद्योगों की आवश्यकता, माँग और आपूर्ति चैनल और सागौन लकड़ी की बाजार दर को समझने में मदद की।

अर्ध–शुष्क परिस्थितियों में उनके अनुकूलन क्षमता के संदर्भ में

व्यापक प्रयोगों ने *पोंगामिया पिन्नाटा* के क्लोनल पौधों और रोपित पौधों में अंतर प्रतिक्रियाओं का पता लगाया है। शुष्क गर्म मौसम के दौरान क्लोनल पौधों की तुलनात्मक बेहतर शारीरिक दक्षता ने अंकुरित पौधों की तुलना में इसकी बेहतर अनुकूलन क्षमता का संकेत दिया। शुष्क गर्म मौसम के दौरान इसकी फोटोकैमिकल दक्षता बनाए रखने के लिए क्लोनल पौधों की बेहतर शारीरिक दक्षता देखी गई है।

मार्कर विश्लेषण के लिए कुल 519 एसएसआर प्राइमरों का उपयोग किया गया था, जिसमें 21 प्राइमरों को इष्टतम स्थितियों के तहत प्रतिलिपि प्रस्तुत करने योग्य प्रवर्धित टुकड़ों के आधार पर चुना गया था। इन 21 प्राइमरों में से 11 प्राइमर अत्यधिक बहुरूपक पाए गए थे, जो 34 ल्युसिना जर्मप्लाज्म की आनुवांशिक विविधता का विश्लेषण करने के लिए प्रयोग किये गये थे। 11 एसएसआर प्राइमर ने कुल 77 एम्प्लिकॉन को 7 एलील प्रति लोक्स के औसत के साथ बढ़ाया। एलील्स का आकार 100 से 800 बीपी तक भिन्न होता है। प्राइमर की जोड़ी AnMtS13 ने अधिकतम 17 एलील का प्रवर्धन किया, जबकि LG100 ने केवल 2 एलील्स का प्रवर्धन किया। इसके अलावा, 34 ल्युसिना अभिगमों के बीच समानता गुणांक का अनुमान NTSYSpc अमत का उपयोग करके जैकार्ड के गुणांक 2.02h से लगाया गया था। समानता गुणांक 0.23 से 0.76 तक था, यह दर्शाता है कि जर्मप्लाज्म के बीच पर्याप्त विविधता है। 0.76 का अधिकतम समानता गुणांक (*ल्युसिना ल्यूकोसेफलौ* 4 और *ल्युसिना ल्यूकोसेफला* – 504) और (*ल्युसिना वर्सिफोलिया*–46/87 और *ल्युसिना विविधिफोलिया*–83) के बीच पाया गया और 0.23 का न्यूनतम गुणांक अंतर, *ल्युसिना ल्यूकोसेफला*–8 और *एल ल्यूकोसेफला* एस –22 में पाया गया। इसके अलावा, क्लस्टर विश्लेषण से पता चला है कि 34 ल्युसिना परिग्रहण को मोटे तौर पर तीन प्रमुख समूहों में बांटा गया था, जिसमें प्रत्येक क्लस्टर पर क्रमशः 17 (क्लस्टर I), 7 (क्लस्टर II) और 10 (क्लस्टर III) परिग्रहण शामिल थे।

इष्टतम नमी और सूखे के तनाव की स्थिति के तहत दोनों मौसमों में *पोंगामिया पिन्नाटा* जीनोटाइप्स के शुरुआती सूखा सहिष्णुता के लिए कार्यात्मक जीनोमिक्स, सभी रूपात्मक लक्षणों के लिए भिन्नता (जीसीवी) की फेनोटाइपिक सह–दक्षता भिन्नता (जीसीवी) से अधिक थी। इससे संकेत मिलता है कि लक्षणों पर पर्याप्त पर्यावरणीय प्रभाव था। अधिकतम नमी की स्थिति के तहत दोनों मौसमों में आरएल और डीआरडब्ल्यू में उच्च आनुवांषिकता (h^2) और आनुवांशिक प्रगति प्रतिशत औसत के अनुसार (जीएएम) थी। हालांकि, h^2,PHT में गर्मी के मौसम में उच्च और बरसात के मौसम में मध्यम पाया गया, जबकि मध्यम h^2 और GAM, दोनों मौसमों में इष्टतम नमी की स्थिति में थे। सूखे के तनाव की स्थिति में, PHT और CHP को छोड़कर अन्य लक्षणों जैसे कि RWC, PRL, ELWL, RL और DRW ने दोनों मौसमों में उच्च h^2 और GAM दर्शाया। इसलिए, उन लक्षणों जिनमें उच्च आनुवांशिकता थी और जो GAM के साथ सूखा तनाव की स्थिति के साथ जुडे हुये थे,के आधार पर जल्दी चयन करने से, पोंगामिया जीनोटाइप के प्रारंभिक सूखा सहिष्णुता के सुधार के लिए उपयोगी हो सकते हैं।

टीकमगढ़ (म.प्र.) के गाँव डाबर में, निकटवर्ती वन क्षेत्रों से लगभग 51 प्रतिशत आवश्यक ईंधन एकत्र किया गया। केवल 65 प्रतिशत महिलाएं ईंधन की लकड़ी का संग्रह करती हैं। गाँव डाबर में, प्रधान मंत्री उज्ज्वला योजना (पीएमयू) के कारण ईंधन की लकड़ी के उपयोग में लगभग 25 प्रतिशत की कमी हुई। 10 प्रतिशत लाभार्थियों के लिए सिलेंडर की रिफिलिंग नियमित नहीं थी। गाँव रौतियाना में, निकटवर्ती वन क्षेत्रों से आवश्यक ईंधन लकड़ी का 68 प्रतिशत एकत्र किया जाता है। यह पाया गया है कि ईंधन की लकड़ी का संग्रह ज्यादातर महिलाओं (85 प्रतिशत) द्वारा किया जा रहा है। गाँव रौतियाना में, उज्ज्वला योजना के कारण ईंधन की लकड़ी के उपयोग में 30 प्रतिशत की कमी देखी गई। सभी लाभार्थियों के लिए सिलेंडर की रिफिलिंग नियमित नहीं थी। गाँव कुंदर में 43 प्रतिशत आवश्यक ईंधन लकड़ी आसन्न वन क्षेत्रों से एकत्र की जाती है। यह पाया गया कि ईंधन की लकड़ी का संग्रह ज्यादातर महिलाओं (70 प्रतिशत) द्वारा किया जा रहा है। गाँव कुंदर में ईंधन की लकड़ी के उपयोग में 50 प्रतिशत की कमी उज्ज्वला योजना के कारण हुई। सिलेंडर की रिफिलिंग नियमित नहीं थी। केवल 25 प्रतिशत लाभार्थियों को नियमित रूप से सिलेंडर भरा जा रहा था। ग्राम सकुली में, निकटवर्ती वन क्षेत्रों से लगभग 54 प्रतिशत आवश्यक ईंधन लकड़ी एकत्र की जाती है। केवल 45 प्रतिशत महिलाएं ईंधन की लकड़ी का संग्रह करती हैं। गांव सकुली में, ईंधन लकड़ी के उपयोग में लगभग 25 प्रतिशत की कमी उज्ज्वला योजना के कारण देखी गई है। 20 प्रतिशत लाभार्थियों को नियमित रूप से सिलेंडर भरा जा रहा था। 5 प्रतिशत लाभार्थियों के लिए सिलेंडर की रिफिलिंग नियमित नहीं थी। गाँव शिवरामपुर में आसन्न वन क्षेत्रों से 79 प्रतिशत आवश्यक ईंधन लकड़ी एकत्र की जाती है। गाँव में

92 प्रतिशतमहिलाएँ ईंधन की लकड़ी का संग्रह करती हैं। गाँव शिवरामपुर में उज्जवला योजना के कारण ईंधन के उपयोग में लगभग 15 प्रतिशत की कमी देखी गई। सभी लाभार्थियों के लिए सिलेंडर की रिफिलिंग नियमित नहीं थी। अन्ना प्रथा (आवारा जानवर) कृषिवानिकी को अपनाने में एक प्रमुख बाधा है।

भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झांसी में, आईसीएआर नेटवर्क प्रोजेक्ट ''प्राकृतिक राल, गोंद एवं गोंद–राल का संग्रहण, प्रसंस्करण एवं मूल्य संवर्धन'' का मुख्य उद्देश्य आजीविका सुरक्षा और प्रौद्योगिकियों के क्षैतिज प्रसार के लिए गोंद और राल–उपज वाले वृक्षों सहित कृषिवानिकी मॉडल विकसित करना है। अनुसंधान गतिविधियों के प्रमुख विषय–i) गोंद पैदा करने वाले वृक्ष आधारित कृषिवानिकी मॉडल की वृद्धि और उत्पादकता, ii) किसानों के खेतों पर गोंद पैदा करने वाले वृक्ष–आधारित कृषि वानिकी मॉडल का प्रदर्शन और विकास और iii) गम और राल दोहन, उपयोग और फसल के बाद के मूल्यवर्धन का स्वदेशी पारंपरिक ज्ञान (ITK) है। चालू वर्ष के दौरान, स्थापित गोंद – पैदावार वृक्ष आधारित कृषिवानिकी मॉडल से अन्तः फसल की वृद्धि सहित उत्पादकता और पैदावार के आंकड़ें दर्ज किए गए थे। इसके अलावा, किसान के खेतों पर स्थापित मॉडल से आंकड़ें दर्ज किये गये थे। वृक्षों की पंक्तियों की उपस्थिति, अन्तः फसल (गेहूं और मूंग) की उपज में महत्वपूर्ण कमी का कारण बनी, जो वृक्षों के आसपास के क्षेत्र में अधिक गंभीर था और वृक्ष से दूरी पर फसल पर कम प्रभाव था। *ए. सेनेगल* से गोंद की पैदावार 1.3 ग्राम से 112.7 ग्राम/वृक्ष तक दर्ज की है जबकि *अकेशिया निलोटिका* में 1.9 ग्राम से लेकर 160.6 ग्राम/वृक्ष विभिन्न मॉडल में दर्ज की गयी। किसानों के खेतों में रोपण के लिए *ए. सेनेगल* और कुछ फलों के पौधों के 22000 पौधे उपलब्ध कराए गए। वर्षा आधारित एग्री–सिल्विकल्चर मॉडल में विभिन्न अंतराल में लगाए गए *अकेशिया सेनेगल* और *अकेशिया निलोटिका* सेबायोमास, कार्बन स्टॉक और कार्बन सीक्वेस्ट्रेशन रेट का अनुमान लगाया गया। दोनों पौधों की प्रजातियों में अधिकतम कार्बन स्टॉक और कार्बन अवशमन दर 5 × 5 मीटर रिक्ति में, उसके बाद 10 × 5 मीटर और 10 × 10 मीटर पर दर्ज की गई। *अकेशिया निलोटिका* ने तुलनात्मक रूप से उच्च कार्बन स्टॉक और कार्बन अवशमन दर दर्ज की। इसके अलावा, संस्थान के अनुसंधान फार्म में स्थापित 10 साल पुराने एग्री–हॉर्टी–सिल्विकल्चर मॉडल का आर्थिक विश्लेषण किया गया। पहले वर्ष के दौरान वार्षिक लाभ : लागत (बी : सी) अनुपात 0.74 था, दूसरे वर्ष में 0.84, और तीसरे से पाँचवें वर्ष के दौरान यह लगभग 1.0 के आसपास स्थिर रहा। इसके बाद, लाभ–लागत अनुपात काफी बढ़ गया और 10वें वर्ष में 2.15 तक पहुंच गया। मॉडल का शुद्ध वर्तमान मूल्य 38,214 था और वापसी की आंतरिक दर (IRR) 18.29 प्रतिशत थी, जो 12 प्रतिशत की ब्याज दर से ऊपर थी। ऋण वापसी अवधि (PBP) 8.41 वर्षों के रूप में पाई गई, जिसका अर्थ है कि 10 वर्षों में खर्च की गई कुल लागत वसूल हो गई है और उसके बाद मॉडल ने केवल शुद्ध लाभ (नेट प्रोफिट) उत्पन्न करना शुरू कर दिया है। *ए. सेनेगल* और *ए. निलोटिका* से प्राकृतिक रूप से निकलने वाले गोंद पर मिट्टी की नमी के प्रभाव पर अध्ययन शुरू किया गया था। मिट्टी की उप–सतह परत (15–30 सेमी) की तुलना में, सतह (0–15 सेमी) में अपेक्षाकृत उच्च मिट्टी की नमी दर्ज की गई थी। सर्दियों की बारिश की अवधि और कृषि–हॉर्टी–सिल्विकल्चर मॉडल में गेहूँ पर लागू सिंचाई की अवधि को छोड़कर समय बीतने के साथ मिट्टी की नमी की मात्रा में गिरावट (सितंबर, 2019 से मार्च, 2020 तक) दर्ज की गई।

असम के कामरूप जिले में आधार रेखा (बेसलाइन) में वृक्ष बायोमास, मिट्टी कार्बन और कुल कार्बन क्रमशः 17.12 Mg DM/ha, 25.47 Mg C/ha और 48.39 MgC/ha है। यह उम्मीद की जाती है कि इन मापदंडों का संबंधित मूल्य 30 वर्षों की सिम्युलेटेड अवधि में क्रमशः 132.34 Mg DM/ha, 42.48 Mg C/ha और 181.29 Mg C/ha तक बढ़ जाएगा। हालांकि, कृषिवानिकी प्रणाली की अनुमानित वार्षिक कार्बन अवशमन क्षमता 4.43 Mg C/ha वर्ष थी। इसके अलावा, सागौन के लिए बायोमास भविष्यवाणी समीकरण, मध्य प्रदेश के सिलवानी में 34 वृक्षों की कटाई द्वारा विकसित किया गया था। सर्वोत्तम प्रतिरूपित प्रतिगमन समीकरण बायोमास (किलो/वृक्ष) = $0.3134 \times (DBH)^{2.034}$ 0.94 के R^2 के साथ है। कृषि–जलवायु क्षेत्र–2 के चयनित जिलों में कृषिवानिकी के अंतर्गत क्षेत्र का अनुमान लगाया गया है। कृषि–जलवायु क्षेत्र–2 के चयनित जिलों में कृषिवानिकी क्षेत्र के मानचित्र भी तैयार किए गए हैं। कृषिवानिकी की दो महत्वपूर्ण वृक्ष प्रजातियों नीम और अल्बिजिया प्रोसेरा (सफेद सिरिस) के थर्मोटॉलरेन्स के संबंध में शारीरिक प्रतिक्रियाओं की गतिशीलता का अध्ययन किया गया है। थर्मोटोलरेंस सूचकांकों जैसे छत्रक तापमान में कमी (CTD) और क्लोरोफिल सामग्री सूचकांक (CCI) ने एक उल्लेखनीय प्रवृत्ति दिखाई है।

उत्तरी भारत के गंगा के मैदानों में, पंजाब, हरियाणा, पश्चिमी उत्तर प्रदेश, उत्तराखंड और बिहार में चिनार प्रजाति आधारित कृषिवानिकी प्रणालियाँ प्रचलित हैं। घरेलू आवश्यकताओं की पूर्ति के लिए इस प्रजाति के लकड़ी उत्पादन को जानने के लिए, चिनार की प्रजातियों के तहत क्षेत्र का मानचित्रण और आंकलन आवश्यक है। पंजाब के 15 जिलों में कृषिवानिकी और चिनार क्षेत्र क्रमशः 176669.95 हेक्टेयर और 31771.62 हेक्टेयर हैं। इन जिलों में कृषिवानिकी क्षेत्र का लगभग 18 प्रतिशत, पोपलर क्षेत्र है। राज्य स्तर पर चिनार का मानचित्रण सेंटिनल–2 ए डेटा के साथ किया गया था। पंजाब राज्य में चिनार की प्रजातियों ने लगभग 0.276 मिलियन हेक्टेयर (5.63 प्रतिशत) के क्षेत्र पर कब्जा कर लिया, जिसमें 81 प्रतिशत की यथोचित सटीकता थी।नीम और सफेद सिरिस के थर्मोटोलेरेंस गतिकी की एक प्रवृत्ति को अस्थायी और मौसमी पैमाने पर देखा गया है इसे CTD और CCI जैसे थर्मोटोलेरेंस इंडेक्स के लिए और पुष्टि की आवश्यकता है।

बुन्देलखण्ड क्षेत्र उत्तर प्रदेश राज्य का पानी की कमी वाले क्षेत्रों में से एक, गरीबी, कुपोषण, भूमि क्षरण और जीविका कमाने के लिए बाहर जाने का प्रमुख स्थान है। इस तरह के मुद्दों को हल करने के लिए भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान ने इक्रीसेट के साथ वर्ष 2011 से 2016 के बीच, 1250 हेक्टेयर क्षेत्र में परासई सिंध जलसमेट की स्थापना की। इसके जलप्रवाह में पारम्परिक हवेली प्रणाली और दूसरी जल संचयन संरचनाओं (ढांचों) के महत्व को दर्शाया है, जो भू–जल पुनर्भरण और फसलों की गहनता को दो से तीन गुणा तक बढ़ा देते हैं तथा घर, पशुओं तथा खेती के लिए जल की उपलब्धता को सुनिश्चित करते हैं। एकीकृत जल प्रबंधन के इन फायदों को महसूस करते हुए, उत्तर प्रदेश सरकार ने इक्रीसेट से अनुरोध किया कि वह किसानों की आय को दोगुना करने की पहल के रूप में, बुन्देलखण्ड के सभी सात जिलों में इसी तरह के कार्य को बढ़ावा दें।

इक्रीसेट ने राष्ट्रीय संस्थानों भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुंसधान संस्थान, झाँसी, भा.कृ.अनु.प.–भारतीय चरागाह एवं चारा अनुसंधान संस्थान, झाँसी, बाँदा कृषि एवं प्रोद्यौगिकी, विश्वविद्यालय, बाँदा, बीएआईएफ तथा स्थानीय गैर सरकारी संगठन जो बुन्देलखण्ड क्षेत्र में स्थित है, को मिलाकर एक संघ का गठन किया। कृषिवानिकी अनुसंधान संस्थान, झाँसी और इक्रीसेट, हैदराबाद का संघ अप्रैल, 2019 तक बन गया था। फसल उत्पादकता पर संतुलित पोषक तत्वों के प्रयोग के प्रभाव दर्शाने के लिए रबी 2018–19 और खरीफ, 2019 के दौरान प्रत्येक प्लाट स्थल पर लगभग 100–150 संतुलित पोषक प्रबंधन के लिए कार्य शुरू किये गये। इसके अलावा 2500 से अधिक किसानों के खेतों में तिल, मूँग, उड़द, गेहूँ, चना, मटर, सरसों की उन्नतकिस्मों की फसल का मूल्यांकन किया गया।

रबी 2018–19 के दौरान झाँसी और जालौन जिलों में कुल 28 किसानों के खेतों (लगभग 60 एकड़) में मृदा प्रबंधन अभ्यास जैसे कि लेजर द्वारा जमीन का समतलीकरण किया गया। ऐसा करने से सिंचाई करने में श्रम और ऊर्जा की लागत में कमी आई तथा जल के उपयोग की क्षमता बढ़ाने में लाभ हुआ। इसके अलावा सौ एकड़ में जीरो टैंग मल्टी क्रोप प्लैण्डर का प्रयोग किया गया, ताकि बीज की मात्रा और खेती की लागत कम हो सके, लाइनों में बुआई को बढ़ावा दिया जा सके तथा सतही मिट्टी की परत में उपलब्ध नमी का अधिक महत्वपूर्ण उपयोग किया जा सके।

मई, 2019 के बाद से बड़े पैमाने पर वर्षा जल संचयन योजना विकसित की गई और प्लाट स्थलों पर लागू करना शुरू किया गया। कुल 13 वर्षा जल संचयन संरचनाएँ जैसे कि चैकडैम, हवेली टैंक, गाँव टैंक बनाए गए/नवीनीकरण किया गया। इसके अलावा कुछ स्थानों पर खेतों में तालाब, जल निकासी के लिए नालों का निर्माण किया गया तथा पानी की उपलब्धता को बढ़ाने और मिट्टी के कटाव (भू–क्षरण) को नियंत्रित करने के लिए 580 एकड़ जमीन में खेतों की मेड़बन्दी या खाई बनाकर मेड़बन्दी की गई। इन सेतु और एक्स सेतु हस्तक्षेपों (कामों) ने लगभग 5,00,000 क्यूबिक मीटर भण्डारण करने की क्षमता बनाई जो कि लगभग 2500 एकड़ में भूमि जल पुनर्भरण की सुविधा प्रदान करेगी ।

इसके अलावा, भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान के साथ सभी सात स्थलों में कृषिवानिकी को शुरू किया गया था। सागौन, नीबू, अमरूद और अन्य फलों के पौधे लगाने के लिए लगभग 85,000 गड्ढों (3 फीट गहराई और 2 फीट चौड़ाई व्यास) की खुदाई की गई। विभिन्न वन विभाग की पौधशालाओं और केन्द्रीय कृषिवानिकी अनुसंधान संस्थान से भी उच्च गुण्वत्ता वाले पेड़–पौधे खरीदे गये। अलग–अलग फलों के वृक्षों के दो साल पुराने कलम बाँधे गए पौधों का चयन किया गया, उनका वितरण किया गया तथा सभी सात स्थलों पर लगाया गया। 228 किसानों के सभी

खेतों में लगभग 2000 स्थानीय बेर के वृक्षों का बडिंग (आँख बाँधना) के जरिये से कायाकल्प किया गया।

संघ ने विभिन्न हितधारकों जैसे कि किसानों, राजमिस्त्री, मृदा उर्वरता प्रबंधन पर गैर सरकारी संगठन के कर्मचारियों, मशीनीकरण, उत्पादकता बढ़ाने, जल संचयन संरचनाओं के निर्माण, कृषिवानिकी आदि के लिए कई क्षमता निर्माण कार्यक्रम शुरू किये। इसके अलावा केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, परासई सिंध जलप्रवाह और स्थलों पर कई हितधारक कार्यशालाओं और समीक्षा बैठक का आयोजन किया गया। अभी तक 11,000 से अधिक किसानों/परिवारों को डीएफआई बुन्देलखण्ड पहल के इस एकीकृत प्रणाली से सीधे लाभ प्राप्त हुआ है। हालांकि बड़े पैमाने पर अप्रत्यक्ष फायदे भी देखे जा रहे है।

''ओड़िशा के बोलांगीर और नुआपाड़ा जिले में कृषिवानिकी और प्राकृतिक संसाधन प्रबंधन के माध्यम से ग्रामीण आजीविका बदलना और प्रवास की जाँच करना'' नामक परियोजना ''ओड़िशा के बोलांगीर और नुआपाड़ा जिलों में कृषिवानिकी प्रणाली के माध्यम से छोटे धारकों को पौष्टिक भोजन का उत्पादन करने में सक्षम करना'' परियोजना की उप–परियोजना है। इस परियोजना का मुख्य उद्देश्य उपयुक्त संरचनाओं के माध्यम से भूमि जल पुनर्भरण को बढ़ावा देना है, ताकि कृषिवानिकी के लिए भूमि उपयोग की सुविधा, फसल और पशुधन उत्पादकता में सुधार और अनुकूलन, प्रवास की जाँच करना और तीन गाँवों के चयनित भागों में सीखने के लिए मॉडल जगहों को विकसित किया जा सकें।इस वर्ष के दौरान बोलांगीर जिले के तारा गाँव में लगभग 25,000 मीटर^3 वर्षा जल संचयन और नुआपाड़ा जिले के बोरीभडी गाँव में लगभग 7000 मीटर^3 वर्षा जल संचयन की क्षमता बनाई गई। तारा और बोरीभडी गाँवों में खेतों की मेड़बन्दी बनाकर उसी जगह पर वर्षा जल संचयन किया गया है। बोलांगीर और नुआपाड़ा जिलों के लिए विभिन्न कृषिवानिकी वृक्षों की प्रजातियों का खेतों की मेड़ों पर वृक्षारोपण और खण्ड वृक्षारोपण की योजना बनाई गई है।

झाँसी के परासई–सिंध जलप्रवाह में सभी खुले उथले कुएं (संख्या–388) जो कि जलसमेट के अकेले सिंचाई के साधन है, महीने के अन्तराल पर उनका जल–स्तर देखने के लिए निगरानी की गई थी। वर्ष के दोरान औसत जल स्तंभ 4.3 मीटर था। मरम्मत किये गये जलप्रवाह से सबसे ज्यादा पानी का बहाव, मरम्मत नहीं किये गये जलप्रवाह से 56 प्रतिशत तक कम था।

समीक्षा वर्ष के दौरान परासई–सिंध जलप्रवाह के किसानों द्वारा उगाई गई प्रमुख फसलें खरीफ मौसम में मूँगफली, मूँग, उड़द तथा रबी मौसम में गेहूँ, सरसों, चना थी। फसल उत्पादकता बढ़ाने के लिए प्रत्येक गाँव की ऊपरी, मध्य और निचले स्तर (पहुँच) से नमूने लिए गये। मूँगफली और गेहूँ के लिए 72 नमूने (3 (निचले, मध्य और ऊपरी स्तर), 3 गाँव, 8 प्रतिकृति) लिये गये। मूँग, उड़द, चना और सरसों की प्रत्येक फसल के मूल्यांकन के लिए 27 नमूने (3 निचले, मध्य और ऊपरी स्तर), 3 गाँव, 3 प्रतिकृति) लिए गये थे। नमूने की प्रत्येक इकाई को 3 मी. x 3 मी. के क्षेत्र से लिया गया था। गेहूँ, सरसों, चने में उत्पाकता क्रमशः 76, 44.7 और 43.3 प्रतिशत थी जो कि मरम्मत किये गये जलक्षेत्र में बिना मरम्मत किये गये जलक्षेत्र की तुलना में ज्यादा थी।

EXECUTIVE SUMMARY

The executive summary of the research and development activities carried at ICAR-Central Agroforestry Research Institute during 2019 is presented here under:

In ber based agri-horti system the observations recorded on different characters (plant growth, pruned material and fruit) of ber were influenced significantly except canopy spread, stone weight, pulp/stone ratio and TSS. In most of the cases the treatment T_8 (ber with 75% RDF + trichoderma + blackgram – barley) showed its superiority, however were at par with T_6 (ber with 75% RDF + VAM + blackgram – barley) and T_2 (ber with 100% RDF + blackgram – barley). Under the system, barley sown during December, 2018 in *rabi*, was harvested during April, 2019 and the observations revealed that treatments T_{10} (pure crop) and T_6 (ber with 75% RDF + VAM + blackgram – barley) recorded highest seed yield of 2498 and 2482 kg /ha in barley and were significantly higher as compared to other treatments. During *kharif*, 2019 blackgram in treatments T_{10} (pure crop) and T_6 (ber with 75% RDF + VAM + blackgram - barley) recorded highest seed yield of 278 and 269 kg /ha and were significantly higher w.r.t. other treatments.

In pomegranate + lemongrass agroforestry system, height ranged from 2.32 m (T_4V_2- Bhagwa with RDCF) to 3.49 m (T_2V_1- Ganesh with 30 kg FYM), collar diameter from 5.55cm (T_2V_2- Bhagwa with 30 kg FYM) to 7.84 cm (T_1V_1- Ganesh with 30 kg vermicompost), East-West spread from 1.72 m (T_4V_2) to 2.85m (T_2V_1) and North-South spread ranged from 1.52 m (T_4V_2) to 2.63 m (T_2V_1). However, fruit yield varied from 4.40 (T_3V_2-Bhagva with 30kg vermicompost +30 kg FYM)) to 6.61 (T_4V_1- Ganesh with RDCF) kg/plant. The cumulative yield from two cuts of lemongrass yielded 12.76 (T_2V_1) to 25.90 (T_5) t/ha green leaves having oil 76.09 T_2V_1 to 265.53 (T_5-Pure lemongrass) kg oil/ha on fresh weight basis.

The project entitled "Structural and functional analysis of short rotation tree based agroforestry system" was started in the year 2016. Under this project, three fast growing tree species *viz.*, *Anthocephalus cadamba, Melia dubia* and *Leucaena leucocephala* have been planted at two spacings i.e. 4 x 5 m and 8 x 2.5 m. The project comprised of seven treatments under each spacing *viz.*, T_1- *Anthocephalus cadamba*+ *crop,* T_2 - *Melia dubia* + *crop,* T_3 - *Leucaena leucocephala* + *crop,* T_4 - *Anthocephalus cadamba* (Pure plantation), T_5 - *Melia dubia* (Pure plantation), T_6 - *Leucaena leucocephala* (Pure plantation) and T_7 - Pure crop *(kharif/rabi)* with three replications under RBD. Blackgram – wheat crop sequence is being taken in this project. The main objectives of the project are to assess growth, biomass and carbon sequestration trends in tree components, to evaluate tree-crop interactions and its impact on crop productivity, and to study the wood properties in relation to fuel wood, pulp & paper industries and small timber. Sixteen numbers of plants of each tree species have been planted in each plot (16 m x 20 m = 320 m^2). Although additional rows of trees have been planted for calculation of carbon sequestration in trees through destructive method. Every year, three trees of each species from 4 x 5 m spacings are being harvested for calculation of biomass and carbon stock in tree components. Eight years rotation age has been fixed for final harvesting of trees and to study the wood properties. Among these fast growing tree species, *M. dubia* attained maximum height and dbh *i.e.* 10.48 m and 151.22 mm when grown in agroforestry and 10.42 m and 164.00 mm in pure plantation at 4 x 5 m spacing. Similarly, maximum dry biomass (102.56 Kg/plant) and carbon stock (51.28 Kg/plant) was also recorded in *M. dubia.* The share of above ground parts and below ground parts to dry biomass was 82.41% and 17.59 %, respectively. The root study revealed that root system was symmetrical in all the tree species *i.e.*

A. cadamba, M. dubia and *L. leucocephala* with maximum root spread in *M. dubia* (4.80 m EW; 4.0 m NS). Shallow primary root system was observed in these tree species. Tap root was 248 cm long in *A. cadamba*, 211 cm in *M. dubia* and 208 cm in *L. leucocephala.* Tap root in *A. cadamba, M. dubia* and *L. leucocephala* was found growing 15-25 cm, 22-25 cm & 15-20 cm vertical in soil, respectively and then growing laterally to some distance before again showing vertical growth. Root system was medium spread type in *A. cadamba*; massive & compact in *M. dubia* and diffused type in *L. leucocephala.* Roots of higher order showed narrow root angles in all the species. The lowest crop yield was observed near the tree row *i.e.* at 1 m distance from the tree row.

The project on "Agroforestry based conservation agriculture (CA) for sustainable landuse and improved productivity project" was initiated during July, 2014 with 03 experiments *viz.*, Bael based Agroforestry system; Teak based Agroforestry system and Bael + Teak based Agroforestry system with 04 main plot treatments *i.e.*, min. tillage-blackgram-mustard (CS-1); min. tillage-greengram-barley (CS-2); CT-blackgram-mustard (CS-1) and CT-greengram-barley (CS-2) and 03 subplot treatments (with crop residue; without crop residue and with leucaena residue).

In bael based CA system the highest seed yield (546.0 kg/ ha) was recorded in crop residue retention treatment followed by leucaena added treatment (529.5 kg/ha). The grain yields of barley ranged from 1218.2 kg/ha (minimum tillage) to 1237.2 kg/ha (conventional tillage) though were non-significant. The addition of crop residue increased the seed yield of barley substantially over no residue treatment. During *kharif* season (2019), the blackgram was recorded seed yield of 154.6 kg/ha in MT plot, which was slightly lower than CT plot (162.7 kg/ha), however the difference was non-significant. The residue addition resulted in significant increase in seed yield of blackgram and yield was recorded as 119.0 kg/ha (no residue) to 142.0 kg/ ha (crop residue). The seed yield of greengram ranged from 154.6 kg/ ha (MT plot) to 162.7 kg/ ha (CT plot). In teak based CA system and in Bael+ Teak based CA system, by and large similar trend was observed among various treatments *w.r.t* tillage treatments and residue retention/ leucaena application.

The observations on growth parameters (DBH and Height) of bael and teak indicated that there were no significant differences between and among the systems for DBH and height of both the tree species. In bael height and DBH varied in the range of 2.69 to 2.92m and 58.81to 67.16mm, respectively. The corresponding values for teak were 4.38 to 4.54 m and 67.64 to 70.98mm, respectively. An appreciably low runoff as well as low soil loss was recorded in minimum tillage based CA system as compared to CT based CA system in greengram-balrey treatments in all the three Agroforestry based CA systems.

In bael based CA system, the organic carbon content varied from 0.367% (CT – blackgram-mustard) to 0.424% (MT–greengram-barley) in 0-15 cm soil depth. The organic carbon content in teak based CA system was recorded as 0.463% in CT- blackgram-mustard based cropping system and 0.532% MT- blackgram-mustard based cropping system in 0-15 cm soil layer. In bael +teak based CA system the OC was recorded as 0.440% (CT-greengram-barley) to 0.547% (MT-blackgram-mustard) in 0-15 cm depth. By and large similar results were recorded in 30-45 cm layer in different AFS. The OC content in soil between 45-90 did not show significant variations. It was evident that in all the systems, the OC content was substantially more upto 45 cm depth in Minimum tillage treatments under greengram-barley cropping system.

In bael based CA system, the organic carbon content varied from 0.367 (CT – blackgram-mustard) to 0.424% (MT – greengram-barley) in 0-15 cm soil depth. The organic carbon content in teak based CA system was recorded as 0.435% in CT-blackgram-mustard based cropping system and 0.512% MT-blackgram-mustard based cropping system in 0-15 cm soil layer. In teak+teak based CA system the OC was recorded as 0.463 (CT-greengram-barley) to 0.532% (MT-blackgram-mustard) in 0-15 cm depth. By and

large similar results were recorded in 30-45 cm layer in different AFS. The OC content between 45-90 cm soil depth did not show any significant variations. In all the systems, the OC content was substantially more upto 45 cm depth in Minimum tillage treatments under greengram-barley cropping system.

In AF based IFS project, average moringa and guava production was recorded 1.50 and 13.26 kg/plant, respectively. Different crops like vegetable pea, sweet corn, wheat, bhindi, bottle guard, pumpkin were successfully grown in Integrated farming system. During 2019, about ` 54180 gross income has been generated from crop and fruit production with 1.38 B: C ratio.

After three year of planting in silvipastoral system, maximum growth parameters of Teak and Mahogani were recorded in treatment having Teak+ Mahogani+ pasture+ contour staggered trenches. Teak growth and survival was recorded higher as compared to Mahogani. Growth parameters and yield of grasses were also observed highest in Teak+ Mahogani+ pasture+ contour staggered trenches as compared to other treatment. During March to June, average soil moisture content was recorded below 2% in all the treatments and which increased upto 12% (in Teak+ Mahogani+ Pasture+ CST) in monsoon season. After third rainy season, soil erosion has been reduced drastically from 15.25 t /ha to 6.14 t /ha in T_7 treatment (TMP + CST) and from 3.19 to 2.08 t /ha in T_6 treatment (TMP+HMB). During rainy season of 2019, total five runoff events were observed and lowest runoff (48.3mm) was observed in T_7 - Teak + Mahogani + Pasture + Contour Staggered Trenches (CST) due to high runoff trapping efficiency (56.3%) and highest runoff (110.6mm) was observed in sole Mahogani treatment. The soil loss as runoff sediment varied between 0.31 t/ha (Teak + Mahogani + Pasture +CST) to 0.72 t/ha (Sole Mahogani).

In horizontal and vertical distribution of fine roots in well-established agroforestry system (AFS), the study revealed that the seasonal mean fine root biomass (FRB) varied largely across different seasons in both *Phyllanthus emblica* and *Hardwickia binata* based AFS. In *Phyllanthus emblica* based AFS majority of the FRB staggered around stem base upto 1.5 m distance and around 70% of it was confined to 0-45 cm soil depth. The annual fine root production rates were highest near to stem base upto 1.0 m distance and the turnover rates varied from 1.63 per year (highest) at 0.5 m distance to 1.03 per year (lowest) at 1.5 m distance from stem base. In *Hardwickia binata* based AFS, 62% of the seasonal FRB found in 0-45 cm soil layer. The fine root turnover rate though less than *Emblica officinalis* based AFS but recorded a value of 1.21 per year (highest) at 0.5 m distance to 0.54 per year (lowest) at 1.5 m distance from stem base.

The dbh of 34 destructively harvested teak trees ranged from 14.94 to 38.42 cm and tree height of 11.2 to 19.00 m. The commercial volume of teak was estimated by using four traditional methods *viz.*, Newton, Huber Smalian and quarter girth over bark gave an average volume of 0.337, 0.332, 0.346, 0.264 m^3/tree, respectively. The average dry biomass and carbon stock of teak trees was 255.51 kg /tree and 127.5 kg /tree, respectively. Diameter at breast height (dbh) alone was found to be a very good predictor of commercial volume. The coefficient of determination in all the fitted function varies 0.92-0.95, whereas Chapman function found better performing over others studied functions.

During field visit, several teak plantation planted at farmers field were monitored and provided critical observations such as uneven, crooked, knotty, diseased growth of teak trees due to absence of tending (pruning & thinning) and cultural operations (weeding, irrigation & fertilizer). Some farmers with the help of forest department, KVKs and private nurseries consists of well managed teak based agroforestry. The visit to timber depot and carpenter industries helped to understand the requirement of industries, demand and supply channels and market rate of teak timber.

Comprehensive experiments have revealed differential responses in clonal plants and seedlings of *Pongamia pinnata* in field with

reference to their adaptability in semi-arid conditions. Comparative better physiological efficiency of clonal plants during dry hot season indicated its better adaptive potential than seedling plants. Better physiological efficiency of clonal plants have been observed in maintaining its photochemical efficiency during dry hot season.

A total of 519 SSR primers were used for marker analysis, in which 21 primers were selected based on reproducible amplified fragments under optimal conditions. Among this 21 primers 11 were found highly polymorphic used to analyze the genetic diversity of 34 *Leucaena germplasm*. The 11 SSR primer amplified a total of 77 amplicon with an average of 7 alleles per locus. Size of alleles varied from 100 to 800 bp. Primer pair AnMtS13 amplified a maximum of 17 alleles, whereas LG100 amplified only 2 alleles. Further, similarity coefficient between 34 Leucaena accessions was estimated by Jaccard's coefficient using NTSYSpc ver. 2.02 h. The similarity coefficient was ranged from 0.23 to 0.76, indicated that substantial diversity among germplasms. Maximum similarity coefficient of 0.76 was observed between (*L. leucocephala* S4 and *L. diversifolia*-504) & (*L. diversifolia*-46/87 and *L. diversifolia-83*) and minimum of 0.23 was observed between *L. Leucocephala* K-8 & *L. leucocephala* S-22. Further, the cluster analysis revealed that 34 *Leucaena* accessions were broadly grouped into three major clusters comprising of 17 (Cluster I), 7 (Cluster II) and 10 (Cluster III) accessions, respectively on each clusters.

Functional genomics for early drought tolerance of *Pongamia pinnata* genotypes in both the seasons under optimum moisture and drought stress condition the phenotypic co-efficient of variation (PCV) was higher than the genotypic co-efficient of variation (GCV) for all the morphological traits considered, indicated that substantial environmental influences over the traits. In both seasons under optimum moisture condition RL and DRW had higher heritability (h^2) and genetic advance as per cent mean (GAM). However, PHT had higher h^2 in summer season and found medium in post rainy season, whereas CHP had medium h^2 and GAM in both seasons under optimum moisture condition. In drought stress condition except PHT and CHP other traits *viz.*, RWC, PRL, ELWL, RL and DRW were showed higher h^2 and GAM in both seasons. Hence, performing early selection based on those traits had higher heritability coupled with GAM under drought stress condition can be useful for improvement of early drought tolerance of Pongamia genotypes.

In village Dabar of Tikamgarh (M.P.), about 51% required fuel was collected from adjacent forest areas. Only 65% women do the collection of fuel wood. In village Dabar, about 25% reduction in fuel wood usage occurred due to Pradhan Mantra Ujjwala Yojana (PMUY). Refilling of cylinders was not regular for 10% beneficiaries. In village Rautiana 68% of required fuel wood was collected from adjacent forest areas. Collection of fuel wood is being performed mostly by women (85%). In village Rautiana 30% reduction in fuel wood usage was observed due to Ujjwala Yojana. Refilling of cylinders was not regular for all the beneficiaries. In village Kundar 43% of required fuel wood was collected from adjacent forest areas. It is found that the collection of fuel wood is being performed mostly by women (70%). In village Kundar 50% reduction in fuel wood usage happened due to Ujjwala Yojana. Refilling of cylinders was nor regular. Only 25% beneficiaries got regular filling of cylinders. In village Sakuli, about 54% required fuelwood was collected from adjacent forest areas. Only 45% women do the collection of fuel wood. In village Sakuli, about 25% reduction in fuel wood usage was observed due to Ujjwala Yojana. Regular filling of cylinders was done with 20% beneficiaries. For 5% beneficiaries refilling of cylinders was not regular. In village Shivrampur 79% required fuel wood was collected from adjacent forest areas. In the village 92% women do the collection of fuel wood. About 15% reduction in fuelwood usage was observed due to Ujjwala Yojana in the village Shivrampur. Refilling of cylinders was not regular for all the beneficiaries. Anna Pratha

(stray animals) is a major constraint in the adoption of agroforestry.

At ICAR-CAFRI, Jhansi, the main aim of ICAR Network Project "Harvesting, Processing and Value Addition of Natural Resins and Gums" is to develop agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies. The major themes of research activities are i) growth and productivity of gum-yielding tree-based agroforestry models, ii) demonstration and development of gum-yielding tree-based agroforestry models on farmers' fields, and iii) indigenous traditional knowledge (ITK) on gum and resin tapping, application and post-harvest value addition. During current year, growth and productivity data including yield of intercrops from established gum-yielding tree-based agroforestry models were recorded. Also, the data were recorded from the models established on farmer's fields. Presence of tree-rows caused significant reduction in yield of intercrops (wheat & mung), which was more severe in vicinity of trees and nullified beyond tree-canopy. Gum yield from *A. senegal* varied from 1.3 g to 112.7g/tree while in *A. nilotica* from 1.9 g to 160.6 g/tree in different models. Approximately, 22000 seedlings of *A. senegal* and some fruit plants were provided for planting on farmers' fields. Biomass, carbon stock and carbon sequestration rate in *Acacia senegal* and *Acacia nilotica*, planted in different spacing, in *rainfed* agri-silviculture model were estimated. Maximum carbon stock and carbon sequestration rate was recorded in 5 × 5 m spacing, followed by 10 × 5 m and 10 × 10 m in both plant species. *A. nilotica* recorded comparatively higher carbon stock and carbon sequestration rate. Besides, economic analysis of a 10-years old agri-horti-silviculture model, established at research farm of the institute, was carried out. During 1st year the annual B: C ratio was 0.74, in 2nd year 0.84, and during 3rd to 5th year it remained almost static around 1.0. Thereafter, the benefit-cost ratio increased considerably and reached up to 2.15 in 10th year. The net present value of the model was ₹ 38,214 and the internal rate of return (IRR) was 18.29%, well above the rate of interest of 12%. The payback period (PBP) was found as 8.41 years implying that the total cost spent in 10 years is recovered and after that model has started generating net profit only. Study on effect of soil moisture content on natural oozing of gums from *A. senegal* and *A. nilotica* was initiated. Relatively higher soil moisture was recorded in surface (0-15 cm) than sub-surface layer (15-30 cm) of the soil. Decline in soil moisture content with passage of time (from September, 2019 to March, 2020) was recorded in all fields, barring period of winter rain and irrigation applied to wheat in agri-horti-silviculture model.

The tree biomass, soil carbon and total carbon in baseline was found as 17.12 Mg DM /ha, 25.47 Mg C /ha and 48.39 Mg C/ha, respectively in Kamrup district of Assam. It is expected that the corresponding value of these parameters would increase up to 132.34 Mg DM/ha, 42.48 Mg C /ha and 181.29 Mg C /ha, respectively over the simulated period of 30 years. However, the estimated annual carbon sequestration potential of agroforestry system was 4.43 Mg C /ha/ year. Apart from this, the biomass prediction equation for teak was developed by harvesting 34 trees at Silwani, Madhya Pradesh. The best modeled regression equations is Biomass (kg tree-1) = $0.3134 \times (DBH)^{2.034}$ with R^2 of 0.94. Area under agroforestry in selected districts of agro-climatic zone-2 has been estimated. Maps of agroforestry area in selected districts of agro-climatic zone-2 has also been prepared. Dynamics of physiological responses in relation to thermos tolerance of two agroforestry important tree species namely *Azadirachta indica* (Neem) and *Albizia procera* (Safed Siras) have been studied. Thermotolerance indices like canopy temperature depression (CTD) and chlorophyll content index (CCI) have shown a notable trend.

In Indo-Gangetic plains of Northern India, poplar species based agroforestry systems are prevalent in Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Bihar. Mapping and estimation of area under poplar species is essential for planners to know wood production from this species to meet domestic requirement. Agroforestry and Poplar area in 15 districts of

Punjab was estimated to be 176669.95 ha and 31771.62 ha, respectively. Poplar area accounted for about 18 % of the agroforestry area in these districts. Poplar mapping at state level was also done with Sentinel-2A data using the methodology described above. Poplar species in Punjab state occupied an area of about 0.276 million ha (5.63%) with a reasonably good accuracy of 81 per cent.

Bundelkhand region of Uttar Pradesh state is one of the water scarce regions, hot spot of poverty, malnutrition, land degradation and out migration. To address such issues, ICAR-CAFRI along with ICRISAT established pilot site called *Parasai-Sindh* watershed of 1246 ha area between 2011 and 2016 Jhansi district. This watershed has demonstrated importance of low cost water harvesting structures including renovation of traditional *haveli* system and other *ex-situ* water harvesting structures which enhanced groundwater recharge and cropping intensity by two to three folds and ensured water availability for domestic, livestock and agriculture. Realizing these benefits of integrated watershed management, Government of UP requested ICRISAT to scale up the similar interventions in all the seven Bundelkhand districts (sites of learning) as part of doubling farmers' income initiative.

ICRISAT initiated process for formation of a consortium of national institutes with ICAR-Central Agroforestry Research Institute (ICAR-CAFRI), Jhansi; ICAR-Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi; Banda University of Agriculture and Technology (BUAT), Banda; BAIF and local NGOs those are based in Bundelkhand region. ICAR-CAFRI, Jhansi and ICRISAT, Hyderabad became consortium partners in April, 2019.

To demonstrate the effect of balanced nutrient application on crop productivity, about 100-150 balanced nutrient management demonstrations were undertaken in each pilot site during *rabi,* 2018-19 and *kharif,* 2019. Improved crop cultivars of sesame, greengram, blackgram, wheat, chickpea, field pea, mustard were evaluated in more than 2500 farmers' fields.

A total 13 rainwater harvesting structures which includes check dam, haveli tanks, village tanks were constructed/renovated. Moreover, farm ponds, drainage channels were constructed at few locations and field bunding or trench cum bunding were made in 580 acres to enhance green water availability and to control soil erosion. These *in-situ* and *ex-situ* interventions created about 500,000 cubic meter storage capacity which would facilitate groundwater recharge in about 2500 acres.

In addition, agroforestry interventions were initiated with ICAR-CAFRI in all the seven pilot sites. Nearly 85,000 quality planting material (teak, lime, guava, mango, aonla etc.) was planted in 7DFI. Nearly 2000 local *ber* trees in 228 farmers' fields are being rejuvenated through budding.

The consortium has undertaken number of capacity building programs for different stakeholders such as farmers, masons, NGO staff on soil fertility management, mechanization, productivity enhancement, construction of water harvesting structures, agroforestry, etc. A number of stakeholder workshops, review meeting, exposure visits were organized at ICAR-CAFRI, Parasai-Sindh watershed and pilot sites. More than 11,000 farmers/families have been directly benefited from this integrated system approach of DFI Bundelkhand initiative; however, there are large scale indirect benefits are also being observed.

The project entitled, "Transforming rural livelihood and check migration through agroforestry in conjunction with natural resource management in Bolangir and Nuapada district of Odisha" is the sub project of "Enabling small holders in Bolangir and Nuapada districts of Odisha to produce nutritious food through agroforestry systems". The main objectives of the project are to enhance groundwater recharge through suitable structures to facilitate agroforestry landuse; to improve and optimize crop and livestock productivity to check the migration and to develop model site of learning in selected patches of three villages. About 25,000 m^3 rainwater harvesting created at Tara

village in Bolangir district and about 7000 m^3 rainwater harvesting capacity has been created at Boirbhadi village in Nuapada district. Insitu rainwater harvesting through field bund preparation has been done in Tara and Boirbhadi villages. Field bund plantation and block plantation of various agroforestry tree species has been planned for Bolangir and Nuapada district.

In Parasai-Sindh watershed of Jhansi, all the open shallow dug wells (388 Nos.), which are only means of irrigation in the watershed were monitored for water table on monthly interval. The average water column during the year was 4.3 m. The peak discharge from treated watershed was 56% lower than untreated watershed.

The major crops grown by the farmers of Parasai-Sindh watershed of Jhansi district during the reporting year were Groundnut, greengram and blackgram (*kharif*) and wheat, chickpea and mustard (*rabi*). In order to substantiate the crop productivity enhancement samples were taken from upper, middle and lower reaches of each village. The productivity of wheat, mustard and chickpea was 76, 44.7 and 43.3%, respectively, higher in treated watershed as compared to base line data.

CHAPTER 1 GENERAL

Mission

To improve quality of life of rural people through integration of perennials on agriculture landscape for economic, environmental and social benefits.

Vision

Integration of woody perennials in the farming systems to improve land productivity through conservation of soils, nutrients and biodiversity to augment natural resource conservation, restoration of ecological balance, alleviation of poverty and to mitigate risks of weather vagaries.

Mandate

- Develop sustainable agroforestry practices for farms, marginal land and wastelands in different agroclimatic zones of India.
- Coordinate network research for identifying agroforestry technologies for inter-region.
- Training in agroforestry research for ecosystem analysis.
- Transfer of agroforestry technology in various agro climatic zones.

9001:2008 Certification

ICAR-CAFRI has been accredited ISO 9001-2015 certificate for its management standards on 18th December, 2019 for the period of three years


GLOBAL CERTIFICATION SERVICES

Certificate of Compliance

This is to Certify That

ICAR-CENTRAL AGROFORESTRY RESEARCH INSTITUTE

NEAR PAHUJ, GWALIOR ROAD,

JHANSI, (U.P.), INDIA.

has been assessed by Global Certification Services and found to comply the requirements of

ISO 9001 : 2015

Quality Management System

FOR THE FOLLOWING ACTIVITIES:

PROVIDING AGROFORESTRY RESEARCH SERVICES.

Initial Date of Certification: 21/12/2019 Current Date of Certification: 21/12/2019

Date of Expiry: 20/12/2022

1st Surveillance Audit November 2020

2nd Surveillance Audit November 2021

Certification Number: GCS/QMS/0353

Authorised signatory Global Certification Services

Laboratories and other facilities

ICAR- CAFRI has a main office building with six well-equipped laboratories. The Institute has conference hall, computer laboratory, committee room and Agroforestry Technology Information Centre (ATIC).

Library

Library is an integral part of the Institute. The Institute's Library is well furnished and equipped with LAN facilities. Library operations are automated using Koha Library Management Software. The library has 4549 books including Hindi books and subscribes 08 Indian Journals. On request references were supplied to the researchers on individual basis as well as through CERA (Consortium for E-Resources in Agriculture) servers through e-mail as well as soft/hard copies. Library also provided Services like Borrowing Facility, Reference Service and Inter Library Loan.

Agriculture Knowledge Management Unit

ICAR-CAFRI obtained 100Mbps Leased Line Internet Connectivity from National Knowledge Net Work, Lucknow. Web server based Ubuntu LINUX has been installed for hosting Institute's web site (www.cafri.res.in).The entire network administration of computers, internet and website management is looked after by the Agriculture Knowledge Management Unit (AKMU).

Research Farm and facilities

The Institutes possesses now 284 acres land (after makeup of 69.48 acres land found excess in the 100 acres initially transferred from ICAR-IGFRI, Jhansi). Out of this about 30 acres land earmarked and handed over for the establishment of Maharani Laxmi Bai Central Agricultural University, Jhansi. Now Institute left about 254 acres land only. Major area is rocky and degraded land which was gradually developed. About 85% arable land have been utilized after phase development for various agroforestry experiments, bulk cropping and block plantations. Research farm possesses seven shallow dug wells but their recharge is very poor

Organizational Setup

DIRECTOR & PROJECT COORDINATOR

- Q R T
- I M C
- RAC
- IJSC

Research Programmes
- System Research
- Natural Resource and Environment Management
- Tree Improvement, Post Harvest & Value Addition
- HRD, Technology Transfer & Refinement

Service Sections
- PME Cell
- Agriculture Knowledge Management Unit
- Liabrary & Documentation
- Administration & Finance
- Farm cum Workshop
- IPR Cell
- Public Information Cell

Network Systems
- AICRPAF

State Agricultural University : Solan, Srinagar, Kahikuchi, Palampur, Ludhiana, Pantnagar, Pusa (Bihar), Faizabad, Jhargram, Bhubaneshwar, Ranchi, Sardarkrushinagar, Fatehpur-Shekhawati, Hisar, Rahuri, Nagpur, Hyderabad, Jabalpur, Dharwar, Mettupalaym, Thrissur, Dapoli, Kattuapakkam, Bengaluru, Jammu (J&K), Shimoga

ICAR Institute : Dehradun, Umiam, Imphal, Gangtok, Karnal, Agartala, Ranchi, Jodhpur, Hyderabad, Jhansi

ICFRE Institute : IFGTB, Coimbatore

- IPR Management
- NICRA
- HPVA of IINRG

due to hard pan (3-5 m below ground). Cultivation is totally dependent on rainfall and operation of canal. During *kharif* season major area was put under green manuring to improve the soil health.

During *rabi* 2019-20 low water requirement crops were sown in concluded projects and general area. Details of cropped area and production and revenue received are given below:

Season / Crop & Variety	Area (ha) Production (Qtls) Revenue received (₹)	Fruits crops 2019-20/Revenue received (₹)	
***Kharif* 2019**		Aonla	51000.00
Blackgram IPU94-1	0.35	Bael	21000.00
Moong IPM 024/Samrat	1.17+ green manuring	Guava	15150.00
Til RT 351	0.72	Lemon	1420.00
Dhaincha	Green manuring	Karonda	1750.00
		Ber	3700.00

During *rabi* 2019-20 about 16.25 ha area have been sown which include 6.80 ha experimental and 9.45 ha general cropping in concluded agroforestry projects. Crop wise area sown in *rabi* season is given below:

Crop	Sown Area		Total
***Rabi* 2018-19**	**Experimental**	**General**	
Wheat DW110/ HD2967	2.70	1.10	3.80
Barley DWRB92	1.10	4.45	5.55
Gram Jaki 9218	-	0.60	0.60
Mustard Giriraj/RH406	1.50	1.30	2.80
Taramira	1.0	2.0	3.00
Pea Arkel	0.50	-	0.50
Total	6.80	9.45	16.25

During the year, a revenue to the tune of ₹ 7.52 lakhs have been generated from Central Research Farm from grains, fruits, firewood, straw and seedling sales. The Central Research Farm facilitated with most improved farm machineries and implements for mechanized farm operations. A mini workshop equipped with welding plants, drill machine, car washer, grinder etc. besides other tools for repair and maintenance of farm machineries is available at the Institute.

MIS/FMS

Five management modules *viz.*, financial, project (project and scheme code generation), stores (indent creation), human resource (training information, applying leaves) and payroll (information related to transfer and joining of employees) have been supported through MIS/ FMS.

Academic

Institute has been recognized by the Bundelkhand University as a study Institute to conduct Ph. D. programme. The Institute conducts M. Sc. dissertation and Ph. D. courses in Agroforestry, Horticulture, Environmental Sciences, Plant Protection, Soil Science, Biotechnology and Soil &Water Conservation from different recognized Universities. Institute contributing to education through UG teaching under collaborate programme with Rani Laxmibai Central Agriculture University, Jhansi.

Budget (2019-20)

(₹ in Lakhs)

S.No.	Head	Budget	Expenditure
1.	**ICAR-CAFRI, Jhansi**		
	a. Capital (grant for creation of Capital Assets)	55.75	55.75
	b. Establishment Expenses (Grant in Aid-Salaries)	835.00	833.45
	c. Grant in Aid-General. Pension Benefits	232.68	232.51
	d. General(including HRD 0.34)	230.00	229.97
	Total	**1353.43**	**1351.68**
	Plan Schemes		
2.	All India Coordinated Research Project on Agroforestry (AICRAF)	1320.86	1320.83
3.	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins (HPVA; ICAR, New Delhi)	18.25	18.08
4.	Assessment of carbon sequestration potential of agroforestry systems (NICRA, ICAR, New Delhi)	27.00	25.85
5.	IP&TM	7.50	7.49
6.	**Externally Funded Projects**		
	Mapping and estimation of area under poplar based agroforestry systems in Indo- Gangetic Plains of India (ICAR- ICRAF Workplan)	3.53	3.05
	Doubling farmers' income in Bundelkhand, UP (ICRISAT)	30.68	27.16
	Establishment of Teak and Aonla based agroforestry system in Datia district on agricultural land (Consultancy project of Bundelkhand Agro)	4.51	0.00
	Establishment of Hi tech nursery for the production of quality planting material (U.P. Agroforestry Mission)	22.18	21.72
	National mission for sustaining the himalayan ecosystems (NMSHE- Taskforce 6 for Himalayan Agriculture)(DST)	14.89	5.08
	Resource Generation	**Target**	**Achievement**
	2019-20	**25.69**	**9.60**
	Expenditure as incurred on Swachhata Action Plan	---	8.76
	SC SP Fund		
	Capital	11.13	9.55
	General	20.00	19.95

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.1: System Research Programme

NRMACAFRISIL201000200085

Nutrient management in ber based agri-horticulture system

(Sudhir Kumar, Rajendra Prasad, Inder Dev and Y N Venkatesh)

As per modified technical program (2012) ten treatments, *viz.* T_1- Ber (100% RDF), T_2- Ber (100% RDF) + Sesame- Lentil, T_3- Ber (75% RDF), T_4- Ber (75% RDF) + Sesame- Lentil, T_5- Ber (75% RDF) + VAM, T_6- Ber (75% RDF) + VAM + Sesame- Lentil, T_7- Ber (75% RDF) + *Trichoderma,* T_8- Ber (75% RDF) + *Trichoderma* + Sesame- Lentil, T_9- Ber (75% RDF) + VAM + *Trichoderma* + Sesame- Lentil and T_{10}- Sesame- Lentil, were imposed before the onset of monsoon by adapting RBD with three replications at the spacing of 6m x 8m. Each treatment having six plants. During IRC 2017, it was decided to change the cropping system and accordingly sesame and lentil replaced by Blackgram and barley. Accordingly, *kharif,* 2017 onwards the technical program is as T_1- Ber (100% RDF), T_2- Ber (100% RDF) + Blackgram - Barley, T_3- Ber (75% RDF), T_4- Ber (75% RDF) + Blackgram - Barley, T_5- Ber (75% RDF) + VAM, T_6- Ber (75% RDF) + VAM + Blackgram - Barley, T_7- Ber (75% RDF) + *Trichoderma,* T_8- Ber (75% RDF) + *Trichoderma* + Blackgram - Barley, T_9- Ber (75% RDF) + VAM + *Trichoderma* + Blackgram - Barley and T_{10}- Blackgram - Barley. The main objective of the experiment is to find out suitable nutrient management schedule for enhanced system productivity, profitability and sustainability under semi- arid conditions and also to observe whether by incorporating the bio- inoculants one can save fertilizer without compromising the production and quality of produce.

The observations recorded on fruits are presented in Table 1. It is evident from the data that all the fruit characters were influenced significantly except stone weight, pulp/stone ratio and TSS. Maximum average fruit weight (23.51g) was found significantly higher in treatment T_8, where as it was minimum (19.76 g) in treatment T_1. Average bigger size fruits were harvested in treatment T_8 (3.53 cm x 3.34 cm) followed by T_2 (3.51 cm x 3.33 cm). Fruit volume ranged from 20.07 cc in treatment T_1 to 24.03 cc in treatment T_8 and found significant. Likewise, pulp weight was recorded maximum in treatment T_8 (21.98 g) and it was minimum in T_5 (18.46 g) and found significant among the treatments. Stone weight, pulp/stone ratio and Total Soluble Solids (TSS) were found non-significant but recorded more in T_8 (1.53 g), T_6 (14.76) and T_6 (13.88^{0}B), respectively whereas it was recorded less in T_1 (1.29 g), T_5 (13.74 g) and T_4 (11.77), respectively. As far as number of fruits/plant is concerned, it was significantly higher in treatment T_8 (4175.03) and lowest in treatment T_2 (2769.7). Fruit yield was significantly more in treatment T_8 (98.02 kg /plant) and found at par with treatments T_6 (83.09 kg / plant).

Table 1: Effect of treatments on fruit characters and yield of ber (cv. Seo) fruits

Treat	Weight (g)	Size (cm) L	Size (cm) W	Volume (cc)	Pulp wt (g)	Stone wt (g)	Pulp/ stone ratio	TSS ^{0}B	No. of fruit / plant	Yield (kg/ plant)
T_1	19.76	3.43	3.25	20.07	18.48	1.29	14.50	12.94	3661.81	72.06
T_2	22.76	3.51	3.33	23.20	21.30	1.46	14.56	12.96	2769.70	61.82
T_3	21.05	3.46	3.26	21.44	19.68	1.37	14.37	12.46	3654.28	76.94
T_4	22.02	3.50	3.32	22.49	20.59	1.43	14.37	11.77	2928.53	64.02
T_5	19.80	3.46	3.28	20.34	18.46	1.35	13.74	12.64	2918.21	56.39
T_6	22.33	3.50	3.34	22.72	20.91	1.42	14.76	13.88	3731.18	83.09
T_7	22.18	3.41	3.21	22.58	20.76	1.42	14.62	13.74	3326.35	73.89

T_8	23.51	3.53	3.34	24.03	21.98	1.53	14.37	12.65	4175.03	98.02
T_9	21.91	3.44	3.30	22.23	20.51	1.40	14.67	13.73	2952.43	64.23
CD (0.05)	2.207	0.073	0.080	2.085	2.129	NS	NS	NS	871.048	20.740

T_1: Ber (100%RDF), T_2: Ber (100%RDF) + Blackgram-Barley, T_3: Ber (75%RDF), T_4: Ber (75%RDF) + Blackgram-Barley, T_5: Ber (75%RDF) + VAM, T_6: Ber (75%RDF) + VAM + Blackgram-Barley, T_7: Ber (75%RDF) + *Trichoderma*, T_8: Ber (75%RDF) + *Trichoderma* + Blackgram-Barley and T_9: Ber (75%RDF) + VAM + *Trichoderma* + Blackgram-Barley

The plants were pruned in the month of May, 2019 (IXth year after planting) and ranged from 13.94 kg to 24.92 kg /plant on fresh weight basis, and 7.47 to 14.53 kg /plant on dry weight basis. In both the cases treatments were found significant (Table 2). After pruning cent percent survival was observed in the field. The plant growth observations recorded in the month of December, 2019 are also presented in Table 2. The data reveals significantly maximum collar diameter in treatment T_1 (14.50 cm) which was at par with treatment T_6 and T_3. Minimum collar diameter was recorded in treatment T_4 (12.30 cm). Canopy spread was found non-significant but observed more in treatment T_8 (6.18 m) for East-West direction and in treatment T_1 (6.27 m) for North-South direction.

Table 2: Effect of treatments on pruned material and plant growth characters of ber (cv Seo)

Treatment	Pruned material (kg/ plant)		Collar diameter (cm)	Canopy spread (m)	
	Fresh	Dry		EW	NS
T_1	24.85	14.53	14.50	6.02	6.27
T_2	15.33	8.44	12.61	5.30	5.36
T_3	20.71	11.74	13.83	6.00	6.04
T_4	13.94	7.47	12.30	4.34	4.27
T_5	21.59	12.55	13.20	5.90	5.97
T_6	20.49	11.58	13.95	5.77	5.78
T_7	21.06	11.69	13.19	5.86	5.83
T_8	24.92	14.37	12.53	6.18	6.17
T_9	18.77	9.93	12.40	5.54	5.67
$CD_{(0.05)}$	6.845	4.066	1.276	NS	NS

Plate 1: Ber pruning

Plate 2 : New flush after pruning

Barley (BHS 400 C/S) was sown (@ 100 kg /ha) on 07th & 08th December, 2018 during *rabi* season on residual fertility under rainfed condition and harvested between 08th to 10th April, 2019. Barley recorded grain yield in the range of 2294 to 2498 kg/ha and corresponding straw yield was recorded in the range of 2462 to 2694 kg/ha in different treatments. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Blackgram - Barley) recorded highest grain yield of 2498 and 2482 kg/ha and were significantly higher as compared other treatments. Similar trend was observed in corresponding straw yield (Table 3). Data indicated that treatments T_{10} and T_6 also recorded significantly higher number of grains/spike.

Table 3: Yield and yield contributing characters of barley during *rabi*, 2018-19 at harvest

Treat	Tillers (per m^2)	Plant height (cm)	Biomass at harvest (DW g/m^2)	Grains/ spike	Seed yield (kg/ ha)	Straw yield (kg/ ha)
T_2	228	77.5	920	33.8	2295	2462
T_4	234	74.3	939	34.1	2310	2496
T_6	232	73.4	825	39.8	2482	2657
T_8	237	72.0	936	34.4	2304	2488
T_9	228	76.4	932	33.9	2294	2472
T_{10}	236	72.8	951	40.5	2498	2694
CV (%)	17.6	18.8	18.2	18.9	17.8	18.6
$CD_{(0.05)}$	NS	NS	NS	3.2	148	182

T_2: Ber (100%RDF) + Blackgram-Barley, T_4: Ber (75%RDF) + Blackgram-Barley, T_6: Ber (75%RDF) + VAM + Blackgram-Barley, T_8: Ber (75%RDF) + *Trichoderma* + Blackgram-Barley, T_9: Ber (75%RDF) + VAM + *Trichoderma* + Blackgram-Barley and T_{10}: (control) Blackgram-Barley

During *kharif*, 2019, Blackgram (urd) variety IPU94-1BS was sown on 19 July, 2019 (15 kg/ha) with recommended dose of nutrients (20:60:30 kg NPK /ha). Data presented in Table 4 indicated that plant population, plant height and biomass accumulation were observed to be non-significant, however, number of pods/plant and seeds/pod were significantly influenced by different treatments. The seed yield varied in the range of 236 to 278 kg/ha and were significantly higher as compared to other treatments. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Blackgram - Barley) recorded significantly highest seed yield of 278 and 269 kg/ha and were significantly higher as compared to other treatments. Similar trend was observed for corresponding straw yield. Plant population, plant height, and biomass per m^2 were not influenced significantly by different treatments. During *rabi*, 2019 barley (var. DWRB-92) was sown on 07 & 16 December, 2019 at the seed rate of 100 kg /ha on residual fertility under rain-fed condition and the production is awaited.

Table 4: Yield and yield contributing characters of Blackgram during *kharif*, 2019 at harvest

Treat	Plant population (per m^{-2})	Plant height (cm)	Biomass (DW g m^{-2})	Seeds pod	Pods plant	Seed yield (kg ha)	Straw yield (kg ha)
T_2	20.8	43.7	98.70	4.79	18.20	236	527
T_4	22.4	41.2	97.40	4.81	18.12	247	543
T_6	21.7	43.0	103.70	4.98	20.10	269	591
T_8	22.6	42.5	94.30	4.83	17.84	252	548
T_9	22.7	40.8	91.80	4.82	17.92	244	534
T_{10}	20.2	39.8	108.60	5.02	21.15	278	602
CV (%)	19.03	18.26	18.36	18.26	17.96	18.64	19.10
CD (0.05)	NS	NS	NS	0.08	1.80	18.60	41.0

T_2: Ber (100%RDF) + Blackgram - Barley, T_4: Ber (75%RDF) + Blackgram - Barley, T_6: Ber (75%RDF) + VAM + Blackgram - Barley, T_8: Ber (75%RDF) + *Trichoderma* + Blackgram - Barley, T_9: Ber (75%RDF) + VAM + *Trichoderma* + Blackgram - Barley and T_{10}: (control) Blackgram – Barley

Plate 3: Ber + Blackgram

Plate 4: Ber + Barley

NRMACAFRISIL201600100099

Performance of pomegranate integrated with lemon grass under organic regime

(Sudhir Kumar, Rajendra Prasad and Y N Venkatesh)

An experiment was laid out during July 2016 after the approval of IRC 2016 in an established pomegranate orchard planted at 5x3m spacing during February 2013. The experiment was designed in CRBD with two cultivars of pomegranate (V_1- Ganesh & V_2- Bhagwa), four levels of fertilizer (T_1- Vermi-compost 30Kg/plant, T_2- FYM 30Kg/ plant, T_3- T_1 + T_2/ plant plant and T_4- Recommended doses of chemical fertilizers/ plant) along with control (T_5) of pure lemongrass. The experiment was replicated thrice and each treatment is having four plants of each cultivars. During July-August, 2016, Krishna variety of lemongrass, procured from CIMAP Lucknow, was planted in between the pomegranate plants at the spacing of 50x40 cm in a plot size of 60 sqm with the area covered in plant basins. During July-August, 2018 due to increase in tussock size, lemongrass spacing converted to 100x80cm by removing one tussock in between the two tussocks. Since, every plant basin is covering 1.0 sqm area and not planted lemongrass in such area therefore the net plot size is 56sqm.

The observations recorded on growth and fruit yield of pomegranate and oil yield of lemongrass on fresh weight basis are presented in Table 5. The data reveals that mean height ranged from 2.32 m (T_4V_2) to 3.62 m (T_2V_1), collar diameter from 5.51 cm (T_2V_2) to 7.90 cm (T_4V_1), East-West spread from 1.72 m (T_4V_2) to 2.85 m (T_2V_1) and North-South spread ranged from 1.52 m (T_4V_2) to 2.63 m (T_2V_1). The fruit yield ranged from 4.40 (T_3V_2) to 6.61 (T_4V_1). During reporting year, plants were not pruned and hence plant height increased over previous year. In general, cv Ganesh is having vigorous growth in comparison to cv Bhagwa and also yielding higher than the cv Bhagwa. The cumulative fresh yield from two cuts (May & October) of lemongrass, yielded 12.76 (T_2V_1) to 25.90 (T_5) t/ha green leaves and 76.09 to 265.53 kg oil/ha on fresh weight basis in treatment T_2V_1 and T_5, respectively.

Table 5: Effect of treatments on growth & yield of Pomegranate and fresh leaves & oil yield of Lemongrass (Lg) on green basis during 2019

Treat	Ht (m)	CD (cm)	EW (m)	NS (m)	Ft. yield (kg/pl)	Lg Fresh (t/ha)	Oil on green basis (kg/ha)
T_1V_1	3.38	7.84	2.44	2.43	6.18	17.49	115.36
T_1V_2	2.88	6.22	1.86	1.88	5.51	16.57	139.39
T_2V_1	3.62	7.83	2.85	2.63	5.83	12.76	76.09
T_2V_2	2.36	5.51	1.92	1.90	5.32	15.08	133.04

T_3V_1	2.82	6.75	1.95	2.04	6.12	14.82	103.27
T_3V_2	2.57	5.88	1.83	1.81	4.40	19.32	118.8
T_4V_1	3.33	7.90	2.41	2.23	6.61	-	-
T_4V_2	2.32	6.35	1.72	1.52	4.75	-	-
T_5 (Lg pure)	-	-	-	-	-	25.90	265.53

T_1V_1- cv. Ganesh with 30 kg vermicompost, T_1V_2- cv. Bhagwa with 30 kg vermicompost, T_2V_1- cv. Ganesh with 30 kg FYM, T_2V_2- cv. Bhagwa with 30 kg FYM, T_3V_1- $T_1 + T_2$, T_3V_2- $T_1 + T_2$, T_4V_1- cv. Ganesh with RDCF, T_4V_2- cv. Bhagwa with RDCF and T_5- Pure lemongrass (control).

NRMACAFRISIL201600200100

Structural and functional analysis of short rotation tree based Agroforestry system

(Naresh Kumar, Asha Ram, Inder Dev, Dhiraj Kumar, Kamini (ICAR-IGFRI, Jhansi), Mahendra Singh and S B Chavan)

The project entitled "Structural and functional analysis of short rotation tree based agroforestry system" was started in the year 2016. Under this project, three fast growing tree species *viz.*, *Anthocephalus cadamba, Melia dubia* and *Leucaena leucocephala* have been planted at two spacings i.e. 4 x 5 m and 8 x 2.5 m. The project comprised of seven treatments under each spacing *viz.*, T_1- *Anthocephalus cadamba*+ crop, T_2 - *Melia dubia* + crop, T_3 - *Leucaena leucocephala* + crop, T_4 - *Anthocephalus cadamba* (Pure plantation), T_5 - *Melia dubia* (Pure plantation), T_6 - *Leucaena leucocephala* (Pure plantation) and T_7 - Pure crop (*Kharif/Rabi*) with three replications under RBD. Blackgram – wheat crop sequence is being taken in this project. The main objectives of the project are to assess growth, biomass and carbon sequestration trends in tree components, to evaluate tree-crop interactions and its impact on crop productivity, and to study the wood properties in relation to fuel wood, pulp & paper industries and small timber. Sixteen numbers of plants of each tree species have been planted in each plot (16 m x 20 m = 320 m^2). Although additional rows of trees have been planted for calculation of carbon sequestration in trees through destructive method. Every year, three trees of each species from 4 x 5 m spacings are being harvested for calculation of biomass and carbon stock in tree components. Eight years rotation age has been fixed for final harvesting of trees. The wood properties of tree species will be studied during final harvesting of tree species *i.e.* at eight years age.

The growth data of tree species was recorded and through destructive method the carbon stock in different parts of *A. cadamba, M. dubia* and *L. leucocephala* was calculated during 2019. Root characteristics of tree species were also studied. Blackgram (*kharif)* and wheat *(rabi)* crops were grown as intercrop and tree-crop interactions were studied.

Height and dbh of tree species

The growth data of trees planted at 4 x 5 m was recorded (Table 6). The average height and dbh of *A. cadamba, M. dubia* and *L. leucocephala* were 6.54 m and 95.87 mm; 10.48 m and 151.22 mm; and 9.25 m and 100.25 mm, respectively when intercrop was taken under these species. Whereas, when these tree species were grown as pure plantations, the respective values of average height and dbh were 5.55 m and 86.29 mm (Cadamba), 10.42 m and 164 mm (Melia) and 9.33 m and 94.41 mm (Leucaena).

Table 6: Average height and dbh of *A. cadamba*, *M. dubia* and *L. leucocephala* planted at 4 x 5 m spacing

Tree species	Height (m)	dbh (mm)	Height (m)	dbh (mm)
	With crop (AF)		Pure plantation	
Cadamba	6.54	95.87	5.55	86.29
Melia	10.48	151.22	10.42	164.00
Leucaena	9.25	100.25	9.33	94.41

The data presented in Table 7 showed that when intercrop was taken under *A. cadamba, M. dubia* and *L. leucocephala* planted at 8x2.5m spacing, their average height and dbh were 5.04 m and 87.60 mm, 9.92 m and 149.00 mm and 8.62 m and 97.67 mm, respectively. However, when these tree species were grown as pure plantation the respective values of height and dbh were 5.24 m and 85.80 mm, 9.18 m and 153.77 mm and 8.72 m and 84.50 mm.

Table 7: Average height and dbh of *A. cadamba, M. dubia* and *L. leucocephala* planted at 8 x 2.5 m spacing

Tree species	Height (m)	dbh (mm)	Height (m)	dbh (mm)
	With crop (AF)		Pure plantation	
Cadamba	5.04	87.60	5.24	85.80
Melia	9.92	149.00	9.18	153.77
Leucaena	8.62	97.67	8.72	84.50

Biomass and carbon stock in tree species

The growth data of tree species were taken before uprooting trees of each species from 4 x 5 m spacing. Three trees of each species were harvested for their biomass, carbon stock estimation and root studies. The average height and dbh of harvested trees of *A. cadamba, M. dubia* and *L. leucocephala* were 6.45 m and 96.00 mm; 9.35 m and 149 mm; and 8.85 and 98 mm, respectively. Excavation was done by manual digging and up-rooting and by using high pressure water to detach soil from roots. Prior to excavation the area around the tree was watered thoroughly to soften the ground and make it possible to excavate without damaging the root system and also to extract entire root system. Different characters of roots were studied. The above ground parts of tree species were separated into stem, leaves and branches. Below ground parts were separated into tap root/primary roots, secondary roots, tertiary roots, quaternary roots and fibrous roots. The fresh weight of above ground parts of tree species was taken separately and thereafter, kept in oven for drying at 70± 2°C till constant weight and then their oven dry weight was measured. Similarly, fresh and dry weight of below ground parts was measured. Carbon stock in all the above ground and below ground parts was calculated by following formula:

Carbon stock= 50% of the oven dry biomass (IPCC, 2006)

In *A. cadamba*, dry biomass and carbon stock were found to be 26.40 and 13.20 kg/plant. Among different parts of the tree, stem contributed maximum to dry biomass (10.38 Kg/tree) and carbon stock (5.19 Kg/plant) which is 39.32% of total dry biomass and carbon stock in the plant. The branch biomass contributed 26.89% to total carbon stock in the tree. Secondary roots' contribution to carbon stock (6.14%) was higher than the primary roots' share (5.45%) (Table 8). Above ground plant parts contributed 84.77% share to total carbon stock whereas below ground parts contributed 15.53% share (Table 9).

In *M. dubia,* dry biomass and carbon stock were found to be 102.56 and 51.28 kg/plant. Carbon stock in leaves, stem, branches and primary root were found to be 14.28, 50.18, 20.05 and 7.81 kg/plant, respectively. The secondary (6.84 Kg), tertiary (2.03 Kg), quaternary (0.87 Kg) and fine roots (0.50 kg) collectively contributed 10.24 kg carbon stock per plant. The maximum carbon stock (25.09 Kg/plant) share *i.e.* 48.93% was found in the stem, whereas branches' share to carbon stock was 19.56% (Table 10). Above ground and below ground plant parts contributed 84.51% share in total carbon stock whereas below ground parts formed 18.05 % share (Table 11).

In *L. leucocephala*, dry biomass, carbon stock was found to be 34.44 and 17.22 Kg/plant. The maximum dry biomass (15.30 Kg/plant) and carbon stock (7.65 Kg/plant) were found in stem which is 44.43% of total dry biomass and carbon

stock. The share of branches and primary root to carbon stock was 19.05% and 10.80%, respectively (Table 12). Above ground and below ground plant parts contributed 27.68 and 6.76 Kg/plant share to dry biomass which is 80.37 and 19.63% of total dry biomass and carbon stock (Table 13).

Root characteristics of tree species

Root system was symmetrical in all the tree species *i.e. A. cadamba*, *M. dubia* and *L. leucocephala* with maximum root spread in *M. dubia* (4.80 m EW; 4.0 m NS). Shallow primary root system was observed in these tree species. Tap root was 248 cm long in *A. cadamba*, 211 cm in *M. dubia* and 208 cm in *L. leucocephala.* Secondary root were 109.02 ± 26.78 cm long in *A. cadamba*; 149.2±11.47 cm in *M. dubia* and 148 ±18.63 cm in *L. leucocephala.* Tertiary root were 94.2 ± 14.41 cm long in *A. cadamba*; 147.2 ± 19.71 cm in *M. dubia* and 84.6 ± 15.80 cm in *L. leucocephala.* Quaternary roots were present in *A. cadamba* (Length: 52 ± 11.45 cm) and *M. dubia* (Length: 118.4±18.207cm) but were absent in *L. leucocephala.* Tap root in *A. cadamba, M. dubia* and *L. leucocephala* was found growing 15-25 cm, 22-25 cm & 15-20 cm vertical in soil, respectively and then growing laterally to some distance before again showing vertical growth. Fibrous root length ranged from 20-32 cm in these tree species. Root system was medium spread type in *A. cadamba*; massive & compact in *M. dubia* and diffused type in *L. leucocephala.* Roots of higher order showed narrow root angles in all the species (Table 14).

Table 8 : Biomass and carbon stock in *A. cadamba*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	4.82	2.41	18.26
2.	Stem	10.38	5.19	39.32
3.	Branches	7.10	3.55	26.89
4.	Primary root	1.44	0.72	5.45
5.	Secondary roots	1.62	0.81	6.14
6.	Tertiary roots	0.92	0.46	3.48
7.	Quaternary roots	0.06	0.03	0.23
8.	Fine roots	0.06	0.03	0.23
	Total	26.40	13.20	100

Table 9 : Share of above ground and below ground parts in carbon stock in *A. cadamba*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	22.30	11.15	84.47
2.	Below Ground	4.10	2.05	15.53
	Total	26.40	13.20	100

Table 10 : Biomass and carbon stock in *M. dubia*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	14.28	7.14	13.92
2.	Stem	50.18	25.09	48.93
3.	Branches	20.05	10.03	19.56

4.	Primary root	7.81	3.91	7.62
5.	Secondary roots	6.84	3.42	6.67
6.	Tertiary roots	2.03	1.01	1.97
7.	Quaternary roots	0.87	0.43	0.84
8.	Fine roots	0.50	0.25	0.49
	Total	102.56	51.28	100

Table 11: Share of above ground and below ground parts in carbon stock in *M. dubia*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	84.51	42.26	82.41
2.	Below Ground	18.05	9.02	17.59
	Total	102.56	51.28	100.00

Table 12 : Biomass and carbon stock in *L. leucocephala*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	5.82	2.91	16.90
2.	Stem	15.30	7.65	44.43
3.	Branches	6.56	3.28	19.05
4.	Primary root	3.72	1.86	10.80
5.	Secondary roots	2.04	1.02	5.92
6.	Tertiary roots	0.68	0.34	1.97
7.	Fine roots	0.32	0.16	0.93
	Total	34.44	17.22	100

Table 13: Share of above ground and below ground parts in carbon stock in *L. leucocephala*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	27.68	13.84	80.37
2.	Below Ground	6.76	3.38	19.63
	Total	34.44	17.22	100

Table 14: Root architecture of *A. cadamba, M. dubia* and *L. leucocephala*

Species/Characters	*A. cadamba*	*M. dubia*	*L. leucocephala*
Root spread			
E-W	4.80 m	3.8 m	3.6 m
N-S	4.00 m	3.6 m	3.8 m
Tap/primary root			
L	248 cm	211 cm	208 cm
D	99.3 mm	120.6 mm	70.60 mm
Secondary roots			
No. per primary root	15 21	12	
L	109.2 ± 26.78 cm (30-140)	149.2 ±11.47 cm (114-184)	148. 00 ±18.63 cm (80-200)
D	48.70± 6.73 mm (12.3-54.18 mm)	103.39± 20.08 mm (18- 46.55 mm)	29.19± 5.15mm (18-46.55 mm)

Tertiary roots			
No. per secondary root	6.6 ± 1.08 (3-10)	10.4 ± 3.03 (3-17)	3.00 ± 0.63(1-5)
L	94.2 ± 14.41 cm (50-131)	147.2 ± 19.71 cm (90-220)	84. 6 ± 15.80 cm (50-150)
D	13.98 ± 3.66 mm (7.32-29.28)	24.43± 4.62 mm (8.22- 39.45)	11.65±1.02 mm (9.62-15.6)
Quaternary roots			
No. per tertiary root	4.2 ± 0.76 (2-7)	6.2±1.03 (3-10)	-
L	52 ± 11.45 cm (50-90)	118.4 ±18.07 cm (70-180)	
D	7.75± 0.74 mm (5.67-10.1)	12.8±1.98 mm (7-20)	
Fibrous roots			
L	20 ±2.5 cm (10-20)	32± 4.5 cm (15-40)	22.06± 7.25 cm (10-27)
D	< 1mm	< 1mm	< 1mm
Root angle			
Secondary Roots	40^{O} - 90^{O}	30^{O} - 70^{O}	50^{O} - 90^{O}
Tertiary Roots	30^{O} - 90^{O}	0^{O} - 70^{O}	20^{O} - 50^{O}
Quaternary Roots	30^{O} - 60^{O}	30^{O} - 80^{O}	-
	Root depth of Tap/ primary root in soil 15-25 cm deep then grows laterally to some distance and then again shows vertical growth	22-25 cm deep then grows laterally to some distance and then again shows vertical growth.	15-20 cm deep then grows laterally. Some distance and then again shows vertical growth.

Tree-crop interactions

The yield data of wheat (*rabi* crop) and blackgram *(kharif* crop) was recorded at different distances from the row of trees. It was observed that yield of wheat as well as blackgram crop was minimum at 1 m distance (*i.e.* nearest to the tree row) from the plants of all the tree species grown at 4x5 m and 8x2.5 m spacings under study. The maximum reduction in crop yield was observed under *M. dubia* (Fig. 1 & 2, Table 14a &14b).

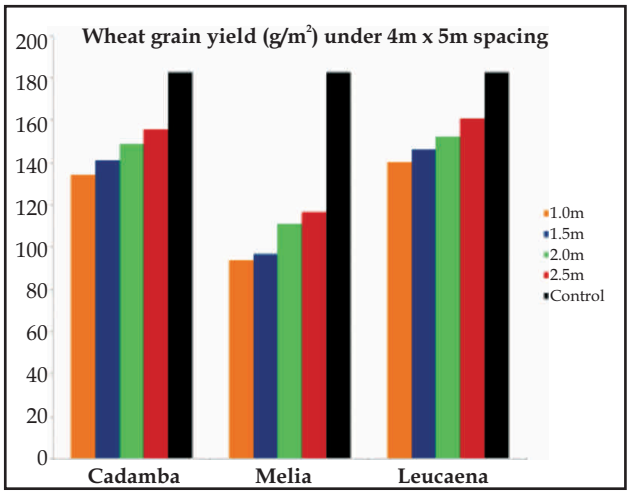

Fig. 1: Yield of wheat crop at different distance from the tree rows planted at 4 x 5 m spacing

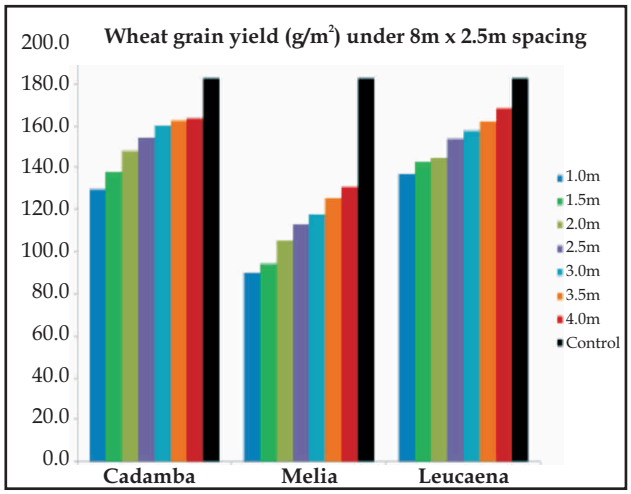

Fig. 2: Yield of wheat crop at different distance from the tree rows planted at 8 x 2.5 m spacing

Table 14a: Yield of blackgram crop at different distances from the tree rows planted at 4 x 5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	2.70	1.85	2.80
1.5 m	2.80	1.88	2.95
2.0 m	2.85	2.25	3.10
2.5 m	3.03	2.40	3.20
Control	3.85	3.85	3.85

Table 14b : Yield of blackgram crop at different distances from the tree rows planted at 8 x 2.5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	2.65	1.80	2.70
1.5 m	2.70	2.05	2.85
2.0 m	2.80	2.10	2.98
2.5 m	2.95	2.23	3.18
3.0 m	3.05	2.33	3.35
3.5 m	3.20	2.50	3.39
4.0 m	3.25	2.65	3.45
Control	3.85	3.85	3.85

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.2: Natural Resource & Environment Management Programme

NRMACAFRISIL201300100091

Agroforestry based conservation agriculture for sustainable land use and improved productivity

(Inder Dev, Asha Ram, Ramesh Singh, Naresh Kumar, KB Sridhar, Dhiraj Kumar, Lal Chand, Mahendra Singh and Y N Venkatesh)

The project on the "Agroforestry based conservation agriculture for sustainable landuse and improved productivity project" was started during July, 2014 having 03 experiments *viz.*, Bael based Agroforestry system; Teak based Agroforestry system and Bael + Teak based Agroforestry system with 04 main plot treatments i.e., Min. tillage-Blackgram-Mustard (CS-1); Min. tillage-Greengram-Barley (CS-2); CT-Blackgram-Mustard (CS-1) and CT-Greengram-Barley (CS-2) and 03 subplot treatments (with crop residue; without crop residue and with leucaena residue). The experiments are being conducted in split plot design with 03 replications.

Experimental results

During *rabi,* 2018-19, mustard (RH 749) and barley (BHS-400 or RH 749) and in *Kharif,* 2019 greengram (IPM 2-3) and blackgram (IPU 94-1) were sown as per the treatment details in all the three experiments, and the results of the experiments are presented as under:

Experiment 1: Bael (*Aegle marmelos*) based conservation agriculture system

In bael based conservation agriculture system, during *rabi,* 2018-19, the seed yield of mustard varied significantly among tillage treatments (Fig. 3). It varied from 513.0 kg /ha under minimum tillage (MT) to 536.0 kg /ha in conventional tillage system (CT). The highest seed yield (546.0 kg /ha) was recorded in crop residue treatment followed by leucaena added treatment (529.5 kg /ha). The seed yield in the treatment of crop residue and leucaena based were statistically at par with each other and significantly higher over the no residue treatment (Table 15).

Plate 5 : Teak + Blackgram in AF based conservation agriculture

The grain yields of barley ranged from 1218.2 kg /ha (minimum tillage) to 1237.2 kg /ha (conventional tillage) though were non-significant (Fig. 4). The addition of crop residue increased the seed yield of barley substantially over no residue treatment (Table 15).

During *kharif* season (2019), the seed yield of blackgram was recorded as 154.6 kg /ha in MT plot, which was slightly lower than CT plot (162.7 kg /ha), however the difference was non-significant (Fig. 5). The residue addition resulted in significant increase in seed yield of blackgram. Yield was recorded as 119.0 kg /ha (no residue) to 142.0 kg /ha (crop residue). The yields of crop residue treatment and leucaena treatment were found statistically at par with each other (Table 15).

Seed yields of greengram in both the tillage treatments were found statistically at par. The seed yield of greengram ranged from 154.6 kg /ha (MT plot) to 162.7 kg /ha (CT plot) (Fig. 6). Addition of crop residue recorded with highest seed yield (165.6 kg /ha) followed by leucaena residue addition (160.4 kg /ha) and least yield was recorded in control (150.1 kg /ha) (Table 15).

Experiment II: Teak (*Tectona grandis*) based conservation agriculture system

In teak based conservation agriculture system, during *rabi* season (2018-19), the seed yield of mustard varied from 506.7 kg /ha in MT plot to 520.0 kg /ha in CT plot (Fig. 3). Due to residue addition significant difference in seed yield of mustard was observed. The seed yield showed substantial increase with crop residue and leucaena addition residue addition over control. However, both the residue addition remained statistically at par with each other (Table 15).

Plate 6 : Bael + Teak + Greengram in AF based conservation agriculture

The data indicated that the grain yield of barley was not influenced by tillage treatments in teak based conservation agriculture system. The grain yield ranged from 1281.6 kg /ha in MT to 1307.4 kg /ha in CT main plot treatment (Fig. 4). In sub plot treatments, crop residue (1349.4 kg /ha) and leucaena residue addition (1306.6 kg /ha) have increased the grain yield of barley substantially over no residue application treatment (1227.5 kg /ha) (Table 15).

Seed yield of blackgram varied from 140.0 kg /ha in MT to 146.0 kg /ha in CT though both the treatments were non-significant (Fig. 5). Among the residue based treatments, the seed yield of blakcgram increased substantially in crop residue addition and in leucaena residue addition over no residue addition treatment (Table 15).

Data in Fig. 6 indicated that tillage treatment did not bring significant change in seed yield of greengram. It varied from 164.5 kg /ha in MT to 171.1 kg /ha in CT plots. Among residue addition, the yield was recorded as 155 kg /ha (no residue addition) to 170.7 kg /ha (in leucaena residue addition) and 177.7 kg /ha (crop residue addition) (Fig. 6) (Table 15).

Experiment III: Bael + Teak based conservation agriculture system

No significant effect of tillage treatments was observed on seed yield of mustard during *rabi* season of 2018-19. However, the seed yield was recorded slightly higher (558.7 kg /ha) in CT plots than MT plot (540.4 kg /ha) (Fig. 3). The residue addition has resulted in significantly increase in the seed yield of mustard over control. Residue addition recorded substantial increase in seed yield in crop residue addition and in leucaena residue addition in sub plots over no residue addition treatment (Table 15).

The grain yield of barley ranged from 1318.8 kg /ha in MT to 1348.7 kg /ha in MT plots (Fig. 4). The residue addition increased the barley yield substantially and it increased from 1274.1 kg /ha (in control) to 1348.4 kg /ha (leucaena residue added plot) and to 1378.6 kg /ha (crop residue added plot) (Table 15).

Plate 7 : Soil sampling with power augur

The data indicated that the seed yield of blackgram was observed statistically at par in both the tillage treatments. The blackgram seed yield ranged from 146.0 kg /ha in MT to 155.4 kg /ha in CT (Fig. 5). The data also indicated that the residue addition had influenced seed yield of blackgram significantly. The highest seed yield was recorded in crop residue added treatment (159.6 kg /ha) followed by leucaena residue added plot (153.5 kg /ha) and minimum in control (139.0 kg /ha). However, both the residue added treatments were found statistically at par with each other (Table 15).

Data also indicated that seed yield level of greengram varied from 178.3 kg /ha in MT to 182.6 kg /ha in CT though both the treatments were non-significant (Fig. 6). Among the residue based treatments, the seed yield of greengram increased substantially in crop residue addition and in leucaena residue addition over no residue addition treatment (Table 15).

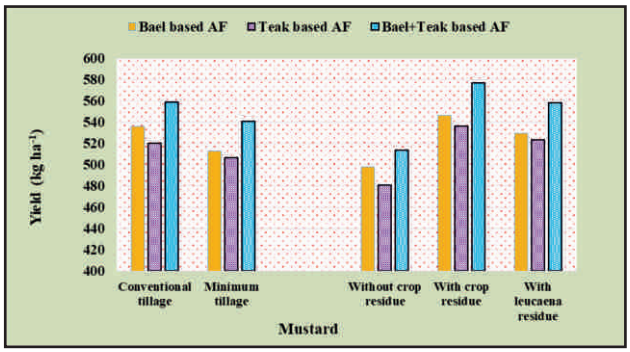

Fig. 3: Seed yield of mustard as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

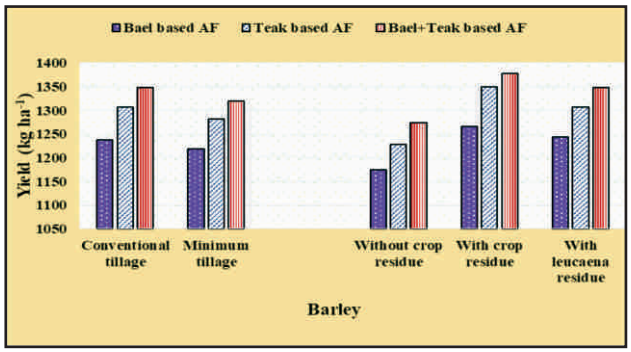

Fig. 4: Grain yield of barley as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

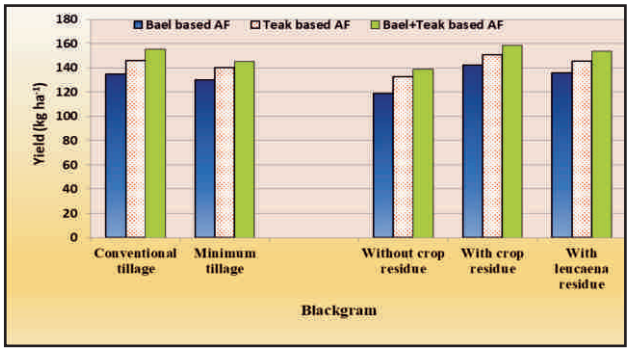

Fig. 5: Seed yield of blackgram as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

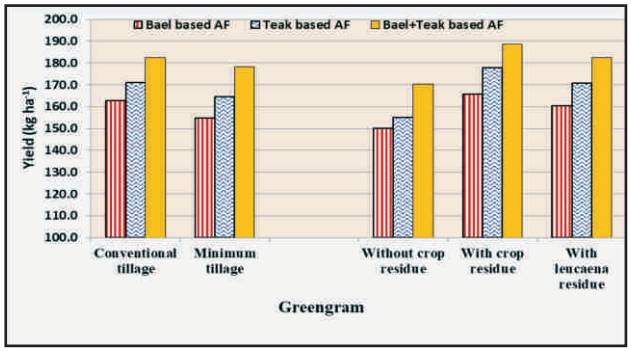

Fig. 6: Seed yield of greengram as influenced by tillage practices under bael, teak and bael+teak based agroforestry system by tillage practices under bael, teak and bael+teak based agroforestry system

Table 15: Yield of GG, BG, Barley and Mustard in AF based CA during 2019

Treatment	Greengram			Blackgram			Barley			Mustard		
	Bael based AFS	Teak based AFS	Bael+ Teak based AFS	Bael based AFS	Teak based AFS	Bael+ Teak based AFS	Bael based AFS	Teak based AFS	Bael+ Teak based AFS	Bael based AFS	Teak based AFS	Bael+ Teak based AFS
Main												
CT- Blackgram -Mustard	-	-	-	134.8	146.0	155.4	-	-	-	536.0	520.0	558.7
CT- Greengram -Barley	162.7	171.1	182.6		-	-	1237.2	1307.4	1348.7	-	-	-
MT- Blackgram -Mustard	-	-	-	129.9	140.0	146.0	-	-	-	513.0	506.7	540.4
MT- Greengram -Barley	154.6	164.5	178.3		-	-	1218.2	1281.6	1318.8	-	-	-
SEm±	2.3	2.1	2.1	1.3	2.0	2.3	6.0	15.9	14.9	11.0	8.9	3.4
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub												
Without crop residue	150.1	155.0	170.2	119.0	132.5	139.0	1174.0	1227.5	1274.1	498.0	480.5	513.5
With crop residue	165.6	177.7	188.7	142.0	151.0	159.6	1265.8	1349.4	1378.6	546.0	536.0	576.9
With leucaena residue	160.4	170.7	182.4	136.0	145.5	153.5	1243.2	1306.6	1348.4	529.5	523.5	558.2
SEm±	2.4	2.3	2.5	2.6	2.8	2.6	14.0	21.1	20.6	9.2	10.3	13.7
LSD (P= 0.05)	7.9	7.5	8.0	8.4	9.2	8.4	45.5	68.9	67.3	30.0	33.7	44.6

CT-Conventional tillage; MT-Minimum tillage

Growth parameters of bael and teak in different AFS based conservation agriculture

The observations on growth parameters (DBH and Height) of bael and teak indicated that there was no significant differences between and among the systems for DBH and height of both the tree species. In bael height and DBH varied in the range of 2.69m to 2.92m and 58.81mm to 67.16mm, respectively. The corresponding values for teak were 4.38m to 4.54 m and 67.64mm to 70.98mm, respectively (Table 16).

Table 16: Growth parameters of bael and teak in different CA based agroforestry systems

Treatment	Bael		Teak	
	DBH (mm)	Height (m)	DBH (mm)	Height (m)
Main plot				
CT-Blackgram-Mustard	58.81	2.92	68.10	4.25
CT-Greengram-Barley	65.64	2.86	68.33	4.41
MT- Blackgram-Mustard	67.16	2.92	67.96	4.54
MT- Greengram-Barley	66.30	2.69	70.98	4.44
SEm±	2.06	0.06	1.07	0.06
LSD (P= 0.05)	NS	NS	NS	NS
Sub plot				
Without crop residue	65.21	2.83	67.64	4.40
With crop residue	65.47	2.86	68.94	4.46
With Leucaena residue	62.75	2.84	69.94	4.38
SEm±	1.06	0.05	0.97	0.05
LSD (P= 0.05)	NS	NS	NS	NS
Main x Sub				
SEm±	65.64	2.86	68.33	4.41
LSD (P= 0.05)	67.16	2.92	67.96	4.54

Runoff and soil loss under Agroforestry based CA systems

During the year 2019, there were 4 rainfall events (Table 17), which suggests that the maximum rainfall of 111.8 mm recorded on 10 July, 2020 and total event rainfall was 286.6 mm. Thus, maximum runoff recorded is in line with maximum rainfall event on 10 July, 2019. A runoff of 30.2 mm recorded in teak based AFS with CT+Greengram-Barley cropping system against 24.6 mm in MT+Greengram-Barley based cropping system. Similarly, in Bael based AFS, the runoff on that day was 26.3 mm in CT+Greengram-Barley based cropping system against 20.6 mm in MT+Greengram–Barley based cropping system. On an average, the total runoff recorded in teak based AFS was 70mm in CT+Greengram-Barley system against 54.6 mm in MT+Greengram-Barley system.

While, in bael based AFS, it was 60.3 mm in CT+Greengram-Barley system against 48.1 mm in MT+Greengram-Barley system. The more interesting finding was that in teak based AFS, CT+Greengram-Barley system recorded 24.4% of runoff against total % event rainfall of 286.6 mm and it was only 19% in case of MT+Greengram-Barley system. While in bael based AFS, total runoff was 21% of event rainfall in CT+Greeengram-Barley system against 16.8% only in MT+Greengram-Barley system. The data of annual soil loss suggests that, 0.62 t/ha was the soil loss in teak based AFS with CT+Greengram-Barley system against 0.49 t/ha in MT+Greengram-Barley system. While in Bael

based AFS, 0.56 t/ha of soil loss recorded in CT+Greengram-Barley system against 0.42 t/ha in MT+Greengram-Barley system.

In Teak+Bael based AFS, the highest runoff (28.6 mm) under CT+Greengram-Barley system and (23.4 mm) under MT+Greengram-Barley system was recorded against the event rainfall of 111.8 mm (Table 17). Further, the total runoff data showed that, it was 65 mm in CT+Greengram-Barley system and 51.1 mm in MT+Greengram-Barley system against total event rainfall of 286.6 mm. Thus, it constitutes 22.7% of event rainfall in CT+Greengram-Barley system and 17.8% in MT+Greengram-Barley system. Similarly, runoff recorded in CT+Greengram-Barley system was 8.8% of annual rainfall (742 mm) and in MT+Greengram-Barley it was 6.9% of annual rainfall. The soil loss correspondingly showed value of 0.59 t/ha in CT+Greengram-Barley system and 0.48 t/ha in MT+Greengram-Barley system. In this way, the minimum tillage recorded an appreciably low runoff as well as low soil loss.

Table 17: Runoff and Soil Loss from various treatment during 2019

Date	Event rain (mm)	Runoff (mm)					
		Teak based AFS		Bael based AFS		Teak+bael based AFS	
		MT+ Green-gram-Barley	CT+ Green-gram-Barley	MT+ Green-gram-Barley	CT+ Green-gram-Barley	MT+ Green-gram-Barley	CT+ Green-gram-Barley
10-Jul-19	111.8	24.6	30.2	20.6	26.3	23.4	28.6
02-Aug-19	57.4	7.46	10.67	6.71	8.38	6.08	9.82
12-Sept-19	88.6	19.32	24.6	18.16	21.8	18.76	22.63
21-Sep-19	28.8	3.2	4.5	2.6	3.8	2.82	3.90
Total	286.6	54.6	70.0	48.1	60.3	51.1	65.0
% of Event Rainfall		19.0	24.4	16.8	21.0	17.8	22.7
% of Annual Rainfall	742	7.4	9.4	6.5	8.1	6.9	8.8
Soil Loss (t/ha)		0.49	0.62	0.42	0.56	0.48	0.59

Organic Carbon content in Bael based CA system

In Bael based AFS, the organic carbon content varied from 0.367% (CT – Blackgram-Mustard) to 0.424% (MT – Greengram-barley) in 0-15 cm soil depth (Table 18). In 15-30 cm soil layer, the OC ranged from 0.246% (CT – Blackgram-mustard) to 0.297% (MT – Blackgram-Mustard) based system. While, the variation was 0.195% OC in CT- Blackgram-mustard to 0.206% in MT – Greengram-Barley based AFS in 30-45 cm soil layer, however the OC content was non-significant within the treatments. The variation in the OC content did not vary significantly in deeper soil layers 45-90 cm. More of the OC was found in minimum tillage main plot treatments followed by conventional tillage systems. Maximum OC content was confined to 0-45 cm soil layer, which registered maximum variation. Further, the impact of residue addition showed that, in 0-15 cm soil depth, OC content was 0.413% in crop residue added plots followed by leucaena residue added plots with value of 0.392% and 0.376% without crop residue plots. In 15-30 cm soil depth, it was 0.297% (crop residue addition), 0.272% (leucaena residue addition) and 0.245% (without crop addition). Further, downward the soil layer, the OC content was non-significant, but it followed by and large similar trend.

Organic Carbon content in Teak based AFS

The organic carbon content was assessed in teak + bael based AFS and it was observed that the organic carbon ranged from 0.435 to 0.512% in CT-Blackgram-Mustard based cropping system and MT-Greengram-Barley based cropping

system in 0-15 cm soil layer (Table 19). Similarly, in 15-30 cm soil depth, it ranged from 0.213% in conventional tillage to 0.269% in minimum tillage based system. The trend in subsequent deeper soil layers *i.e.*, from 30-90 cm soil depth was by and large similar. The assessment of impact of residue addition on soil organic carbon indicated that, it was more in case of plots with crop residue addition followed by leucaena residue incorporation and least in no residue addition. The values were 0.524% in crop residue added plots followed by 0.471% in leucaena residue added plots and 0.420% in plots with no residue addition in 0-15 cm soil depth. In 15-30 cm soil depth, the corresponding values were 0.258% with crop residue, 0.232% with leucaena residue and 0.220% without crop residue. In deeper soil layers 30-90 cm not much variation was observed for organic carbon content.

Table 18: Organic Carbon Content in Bael based CA system

Treatment	0-15 cm	15-30 cm	30-45 cm	45-60 cm	60-75 cm	75.90 cm
Main						
CT- Blackgram -Mustard	0.367	0.246	0.195	0.134	0.116	0.093
CT- Greengram -Barley	0.400	0.263	0.201	0.137	0.123	0.094
MT- Blackgram -Mustard	0.384	0.280	0.204	0.148	0.128	0.086
MT- Greengram -Barley	0.424	0.297	0.206	0.147	0.128	0.086
SEm±	0.007	0.004	0.006	0.003	0.004	0.004
LSD (P= 0.05)	0.024	0.015	NS	NS	NS	NS
Sub						
Without crop residue	0.376	0.245	0.200	0.140	0.121	0.091
With crop residue	0.413	0.297	0.203	0.142	0.121	0.087
With leucaena residue	0.392	0.272	0.201	0.142	0.129	0.092
SEm±	0.005	0.003	0.003	0.003	0.003	0.003
LSD (P= 0.05)	0.014	0.010	NS	NS	NS	NS

Table 19: Organic Carbon Content in Teak based CA system

Treatment	0-15 cm	15-30 cm	30-45 cm	45-60 cm	60-75 cm	75.90 cm
Main						
CT- Blackgram -Mustard	0.435	0.213	0.176	0.150	0.120	0.100
CT- Greengram -Barley	0.453	0.227	0.167	0.147	0.122	0.103
MT- Blackgram -Mustard	0.486	0.238	0.189	0.150	0.122	0.104
MT- Greengram -Barley	0.512	0.269	0.181	0.159	0.126	0.104
SEm±	0.004	0.002	0.005	0.005	0.004	0.003
LSD (P= 0.05)	0.014	0.006	NS	NS	NS	NS
Sub						
Without crop residue	0.420	0.220	0.175	0.146	0.121	0.104
With crop residue	0.524	0.258	0.185	0.151	0.120	0.103
With leucaena residue	0.471	0.232	0.176	0.157	0.126	0.101
SEm±	0.006	0.004	0.005	0.004	0.002	0.002
LSD (P= 0.05)	0.019	0.011	NS	NS	NS	NS

Organic carbon content in Teak + bael based CA system

The organic carbon content data for Teak based AFS indicated that in 0-15 cm soil depth, among tillage based main plot treatments, it varied from 0.463% (CT-Blackgram-mustard) to 0.532% (MT-Greengram-barley) based systems (Table 20). While, in 15-30 cm soil depth, it varied from 0.321% (CT-Blackgram-mustard) to 0.359% (MT-Greengram-barley). Similarly from 45-90 cm, the OC content was non-significant with higher OC content in minimum tillage over conventional tillage systems. In the sub plot treatments of residue addition in 0-15 cm soil layer, the OC ranged from 0.462% (no residue addition), to 0.497% (leucaena residue addition) and subsequently, 0.462% (crop residue addition). While in 15-30 cm soil depth, it was 0.312% (without crop residue), 0.345% (leucaena residue) and 0.364% (crop residue addition). In 30-90 cm soil depth the OC content was non-significant, however by and large similar trend was observed as was observed in 0-30 cm soil depth.

Table 20: Organic Carbon Content in Teak+Bael based CA system

Treatment	0-15cm	15-30cm	30-45cm	45-60cm	60-75cm	75.90cm
Main						
CT-Blackgram-Mustard	0.463	0.321	0.310	0.216	0.141	0.124
CT-Greengram-Barley	0.483	0.338	0.308	0.210	0.140	0.125
MT-Blackgram-Mustard	0.504	0.344	0.312	0.224	0.137	0.129
MT-Greengram-Barley	0.532	0.359	0.318	0.226	0.135	0.122
SEm±	0.004	0.003	0.006	0.006	0.002	0.002
LSD (P=0.05)	0.013	0.011	NS	NS	NS	NS
Sub						
Without crop residue	0.462	0.312	0.311	0.212	0.140	0.124
With crop residue	0.528	0.364	0.313	0.225	0.137	0.129
With leucaena residue	0.497	0.345	0.312	0.220	0.138	0.122
SEm±	0.004	0.004				
LSD (P=0.05)	0.013	0.011				

RMACAFRISIL201600400102

Agroforestry based Integrated Farming System for small and marginal farmers in semi-arid region

(Ram Newaj, Asha Ram, Sudhir Kumar, Dhiraj Kumar, Ramesh Singh, Naresh Kumar, Mahendra Singh, Y N Venkatesh and R Vishnu)

Project on Agroforestry based Integrated Farming System (AF-IFS) was initiated during November 2016. The enterprises proposed for AF-IFS model and land allotted for each enterprise is given in Table 21. Guava was planted on bunds at 10m spacing (R x R) and 100 per cent survival was observed in year 2019. Average guava fruit production was recorded 13.26 kg/plant. However, mortality per cent in mango was recorded very high. Teak was also planted on field boundaries and bunds and gap filling was done as per requirement. Moringa planted on road side as well as on field boundary started fruiting and recorded with average production of 1.50 kg pod/plant (Plate 8). During *rabi* 2018-19, pea was grown in 0.7 ha area, and about 541 kg green pod and 135 kg pea grain was produced. Wheat crop was produced (1195 kg) in 0.4 ha area (Table 22). In Jaid season, availability of irrigation water is main problem so only 0.25 ha area was covered under maize and vegetables (bhindi, pumpkin, bottle guard). In *kharif* season, only Bhindi was grown in 0.1 ha area and in rest area green manuaring was done

with cow pea and dhaincha. In year 2019, from crop and fruit production about ₹ 54180 gross income has been generated with 1.38 B: C ratio. During August 2019, fish fingerlings were introduced in pond but all were lost due to overflow of pond after very heavy rain. The goat keeping and poultry could not initiated due paucity of funds in third phase.

Table 21: Agroforestry based IFS model for 1.55 ha land

Enterprise		Area (ha)	Activities
1.	Agroforestry	1.22	Roadside plantation-Moringa, Boundary plantation-Teak
i	Agrihorticulture system	0.45	Guava + Papaya + crops
ii	Vegetable based	0.52	Vegetables- Bhindi, vegetable pea, bottle guard, pumpkin
ii	Crop based (Foodgrains)	0.25	Sweet corn, Blackgram, Wheat, Chickpea
2.	Poultry	0.03	Not started
3.	Fishery	0.22	Rearing of fishes (Catla and Rohu)
4.	Goat keeping	0.075	Not started
5	Composting	0.01	Composting with crop residue
	Total	1.55	

Table 22: Crop production and economic analysis of agroforestry based IFS model for the year 2018-19

Season	Area (ha)	Crop	Production (kg)	Cost of cultivation (Rs.)	Gross income (Rs.)	B:C ratio
Winter (*Rabi*)	0.7	Pea (green pod)	541	39200	54180	1.38
		Grain	135			
	0.4	Wheat	1195			
	0.3	Chickpea	17			
	40 plants	Guava	491			
Summer (*Zaid*)	0.25	Bhindi	153			
		Bottle gourd	30			
		Pumpkin	50			
		Maize	140 cob			
		Moringa (Pod)	60			
Rainy (*Kharif*)	0.1	Bhindi	57			
	0.9	Cowpea for green manuring				

Plate 8: Moringa on road side at IFS

Plate 9: Sweet corn (Zea mays saccharata) in Guava based AFS

NRMACAFRISIL201600500103

Impact of watershed and agroforestry interventions on hydrology and nutrient loss at Garhkundar-Dabar watershed in Bundelkhand region of Central India

(Ramesh Singh and Dhiraj Kumar)

Monitoring of runoff and soil loss was done at five locations in Garhkundar-Dabar watershed (treated), however, untreated watershed was gauged for the same at the outlet. Datalogger based automatic stage level recorders were installed at six sites, including control watershed during 2019. Besides this, manual and self-recording rain gauges were also installed in the watershed to measure the rainfall. Total 834.6 mm rainfall, 4.8% deficit than normal, was received.

It was observed that the runoff from the treated watershed was 11.7% of total recorded rainfall during the year. Soil loss from treated and untreated was also recorded and it was 79.4% lower in case of treated over untreated watershed.

All open shallow dug wells in treated (116 nos.) and untreated (42 nos.) watershed were monitored monthly for water level. During the month of October average water column was 4.6 m which is 36% higher than the average water column of open wells situated in untreated watershed. The N and P loss were 4.21 and 2.23 kg/ ha, respectively, from treated watershed.

NRMACAFRISIL201600700104

Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions

(Asha Ram, Inder Dev, Ramesh Singh, Naresh Kumar and Dhiraj Kumar)

The project on "Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions " was started during *Kharif* season of 2016 with seven treatments comprising of T_1- Sole Pasture; T_2- Sole Teak (*Tectona grandis*); T_3-Sole Mahogani (*Swietenia Mahogani*); T_4-Teak+Mahogani+ Pasture; T_5-Teak + Mahogani + Pasture + halfmoon basin (HMB); T_6-Teak+Mahogani+Pasture+ Vegetative Hedge (VH); T_7-Teak+Mahogani+ Pasture + Contour Staggered Trenches (CST). The experiment was laid out in Randomized Block Design and replicated thrice.

Experimental Results

The survival of the teak and mahogani after two year of transplanting was observed to be 91 and 75%, respectively. After two year of planting, maximum height and collar diameter of teak and Mahogani were recorded in treatment having Teak+ Mahogani+ Pasture+ Contour staggered trenches (Table 23). Grass cut was taken in month of September and highest growth parameters and yield were recorded in T_7 - Teak+Mahogani+ Pasture + Contour Staggered Trenches (CST) treatment followed by T_6- Teak+Mahogani+ Pasture +HMB (Table 24). All the soil and moisture conservation measures were observed to increase the grasses yields (Fig. 7). The root parameters of both the grasses were also found significantly higher in T_7 - Teak+Mahogani+ Pasture + Contour Staggered Trenches (CST) treatment as compared to other treatments (Table 25). Soil moisture dynamics in different treatments were studied through thermo-gravimetric method at 15 days interval and it was found that soil and moisture conservation measures increases the availability of soil moisture in soils. During March, April, May and June, average soil moisture content was recorded below 2% in irrespective of all the treatments and reaches upto 12% (in Teak+ Mahogani+ Pasture+ CST) in Month of August (Fig. 8). Among all the treatments, highest moisture content was recorded in T_7 treatment due to contour staggered trenches, followed by T_6. Sole tree (Teak /Mahogani) plantation (without pasture component) observed with lowest moisture conservation due to direct exposure of soil surface to sunlight, wind etc. After three years of experimentation, soil erosion is reduced drastically due increased vegetation and stability of soils. After third rainy season, the contour staggered trenches (CST) and half-moon basin (HMB) trapped soil sediments at the rate of

6.14 t /ha and 2.08 t /ha, respectively (Fig. 9). During rainy season of 2019, total five runoff events (324.5 mm event rainfall) were observed and lowest runoff (48.3mm) was observed in T_7 - Teak+Mahogani+ Pasture + Contour Staggered Trenches (CST) treatment due to high runoff trapping efficiency (56.3%) and highest runoff (110.6mm) was observed in sole Mahogani treatment (Table 26). The soil loss as runoff sediment varied between 0.31 t/ha (Teak +Mahogani +Pasture+ CST) to 0.72 t/ha (Sole Mahogani). Similar results were found in total (runoff and sediment) nutrient losses.

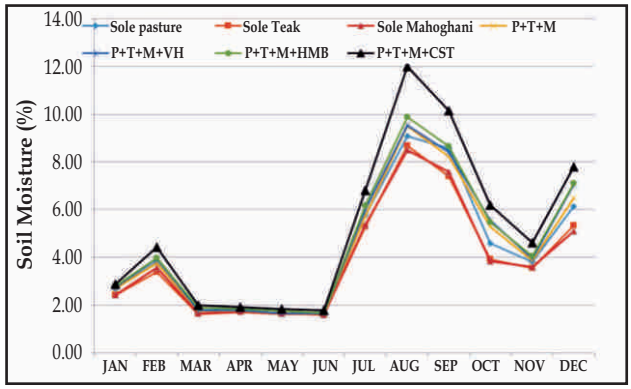

Fig. 8 : Soil moisture dynamics in different treatments during year 2019

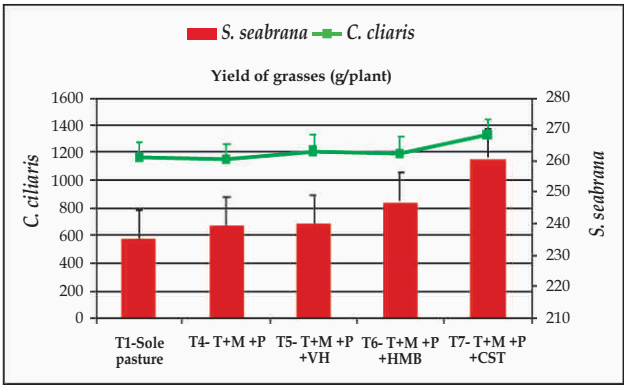

Fig. 7 : Grass yield (Fresh weight) of *C. ciliaris* and *S. seabrana*

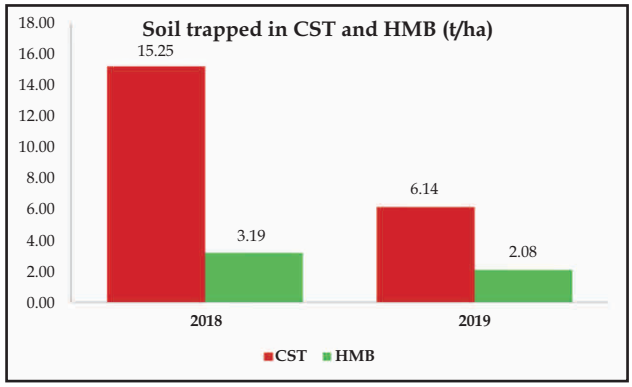

Fig. 9 : Soil trapped in trenches and Half Moon Basin during 2018 and 2019

Table 23: Height and collar diameter of Teak and Mahogani after three year of planting

Treatment	Teak		Mahogani		
	Height (cm)	C.D.	DBH	Height (cm)	C.D.
T_1-Sole pasture	-	-	-	-	-
T_2-Sole Teak	398.0	69.5	46.7	-	-
T_3-Sole Mahogani	-	-	-	189.0	46.8
T_4- T+M +P	405.0	72.1	48.9	199.0	48.1
T_5- T+M +P +VH	415.0	74.7	51.7	208.0	50.2
T_6- T+M +P +HMB	438.0	76.2	54.1	215.5	51.7
T_7- T+M +P +CST	455.1	80.8	57.0	225.0	53.0
SEm±	9.0	2.1	1.4	4.0	1.0
LSD (P=0.05)	29.2	6.8	4.5	13.2	3.2

Table 24: Growth parameters and yields of *Cenchrus ciliaris* and *Stylasanthus seabrana*

Treatments	*Cenchrus ciliaris*			*Stylasanthus seabrana*		
	Height (cm)	No.of tiller/ tussock	Tussock Diameter (cm)	Height (cm)	No.of Primary branch/plant	No.of Secondary branch/plant
T_1-Sole pasture	130.67	150.7	38.60	83.10	7.58	13.6
T_2-Sole Teak	-	-	-	-	-	-

T_3-Sole Mahogani	-	-	-	-	-	-
T_4-T+M+P	134.17	147.8	37.17	81.30	7.65	13.2
T_5-T+M+P+VH	130.77	152.5	39.20	80.67	7.57	13.2
T_6-T+M+P+HMB	133.67	154.7	40.17	84.73	7.77	14.1
T_7-T+M+P+CST	137.07	164.3	41.60	85.70	7.87	14.9
SEm±	1.74	2.5	0.91	1.28	0.24	0.3
LSD(P=0.05)	5.67	8.1	2.96	4.17	0.78	1.1

Table 25: Root growth parameters of *Cenchrus ciliaris* and *Stylosanthes seabrana*

Treatment	*Cenchrus ciliaris*				*Stylosanthes seabrana*				
	Root depth (cm)	Root spread (cm)	No.of rootsper tussock	Root diameter (mm)	Dry weight roots (g)	Main root length (cm)	Main root diameter (mm)	Total No. primary roots/plant	Primary root diameter (mm)
Sole pasture	26.33	38.87	663.67	0.98	100.81	20.4	11.77	20.3	1.70
P+T+M	26.10	39.00	652.67	0.97	107.35	20.8	11.37	20.7	1.69
P+T+M+VH	26.11	38.96	672.00	1.01	106.29	21.6	11.85	21.5	1.78
P+T+M+HMB	26.61	39.23	695.33	1.02	110.02	22.9	12.12	21.8	1.77
P+T+M+CST	27.43	40.77	760.67	1.05	122.69	23.3	12.37	22.3	1.83
SEm±	0.73	0.46	20.21	0.02	2.60	0.9	0.22	0.6	0.03
CD 5%	NS	1.52	65.89	0.06	8.47	2.9	0.73	2.0	0.10

Table 26: Runoff and Soil Loss from various treatment during 2019

S.No	Date	Event	Runoff(mm)						
		Rain (mm)	T_1-Sole pasture	T2-Sole Teak	T_3-Sole Mahogani	T_4-T+ M+P	T_5-T+ M+P+VH	T_6-T+ M+P+HMB	T_7-T+ M+P+CST
1	10-Jul-19	111.8	35.2	38.2	40.2	41.2	36.5	34.6	25.6
2	02-Aug-19	57.4	12.9	9.7	12.1	9.8	10.7	8.2	5.8
3	12-Sep-19	88.6	21.5	33.6	36.2	17.5	15.6	12.5	9.5
4	21-Sep-19	28.8	13.2	9.8	11.2	8.6	7.2	6.2	4.2
5	02-Oct-19	37.9	11.3	9.6	10.9	7.6	5.6	5.2	3.2
	Total	324.5	94.1	100.9	110.6	84.7	75.6	66.7	48.3
% of 324.5 mm Event Rainfall		29.0	31.1	34.1	26.1	23.3	20.6	14.9	
% of 742 mm Annual Rainfall			12.7	13.6	14.9	11.4	10.2	9.0	6.5
Soil Loss (t/ha)			0.56	0.63	0.72	0.48	0.41	0.39	0.31

(a) Vegetative Hedge of *S. aegyptica*

(b) Infiltration study

(c) Root study of *C. ciliaris* and *S. seabrana*

(d) Vegetation coverage after three years of experiment

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Horizontal and vertical distribution of fine roots of tree and nutrients content in well-established Aonla and *Hardwickia binata* based agroforestry system

(Dhiraj Kumar, Ram Newaj, Rajendra Prasad and Asha Ram)

The present study was initiated during 2016-17. The spacing in *Emblica officinalis* (Aonla) and *Hardwickia binata* (Anjan) was 10x10 m and 10x5 m, respectively. The Aonla were planted in the year 1996 and *Hardwickia binata* in the year 1991. The crop cycle in Aonla based AFS was greengram-mustard and in *Hardwickia binata*, blackgram-wheat. Horizontal stratified sampling was done from six distances 0.5 m, 1.0 m, 1.5m, 2.0 m, 2.5 m and 3.0 m. Similarly, in vertical stratified sampling, soil samples were collected from six depths *i.e.*, 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm, 60-75 cm and 75-90 cm, respectively. The fine root samples were collected in three seasons, summer, autumn and winter seasons. Further, from that the mean seasonal fine root biomass was computed which is presented in Fig. 10 and Fig. 112, respectively.

The seasonal FRB in *Emblica officinalis* based AFS varied largely across different depths as well as distances from stem base (Fig. 10). Along different distances from stem base, *viz.*, 0.5 m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0m, the FRB varied from 28-152, 26-121, 26-93, 18-85, 32-105 and 26-79 g /m^2, respectively. Mainly, 70% of the FRB confined to 0-45 cm soil depth as compared to lower depths.

In case of *Hardwickia binata* based AFS, the FRB were found to be higher than that of *Emblica officinalis* based AFS. The seasonal FRB largely aggregated towards nearer to the stem base upto 1.5 m distance from stem base (Fig. 11). Around 62% of the seasonal mean FRB confined to 0-45 cm soil depth as compared to 45-90 cm soil layer. The variation of seasonal FRB along different distance from stem base *i.e.*, 0.5m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0 m showed values ranging from 175-737, 168-714, 390-650, 285-576, 256-574 and 196-408 g /m^2, respectively.

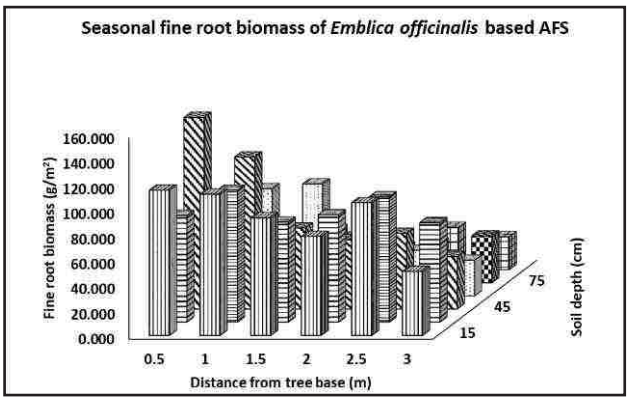


Fig. 10 : Seasonal fine root biomass (g/m^2) of *Emblica officinalis* based AFS

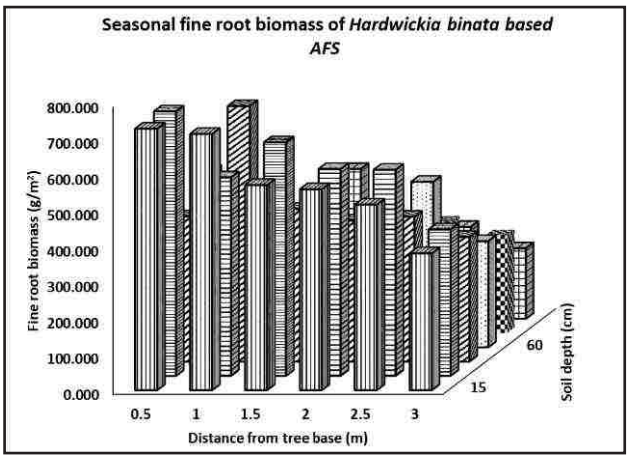


Fig. 11 : Seasonal fine root biomass (g/m^2) of *Hardwickia binata* based AFS

Seasonal maximum fine root biomass (FRB) of *Emblica officinalis* based AFS ranged from 79 ± 2.6 g /m^2 at 3.0 m distance from stem base to 152 ± 2.6 g /m^2 at 0.5 m distance from stem base (Table 27). While, minimum fine root biomass ranged from 18 ± 0.7 g /m^2 at 2.0 m distance from stem base to 32 ± 1.1 g /m^2 at 2.5 m distance from stem base. Across different distance from stem base, 58% of mean FRB confines to 1.5 m distance from stem base. Fine root production rates were high within 1.0 m distance from stem base with values of 124 g /m^2/year at 0.5 m and 95 g /m^2/year at 1.0 m from stem base. Mostly, the annual fine root production rates were high across near proximity to the stem base, indicating availability of moisture and nutrients. The fine root turnover rates ranged from 1.03 /year at 1.5 m distance from stem base to 1.63 /year at 0.5 m distance from stem base (Table 27)

The maximum seasonal fine root biomass in *Hardwickia binata* based AFS ranged from 408 ± 7.9 g /m^2 at 3.0 m distance from stem base to 737 ± 6.3 g /m^2 at 0.5 m distance from stem base (Table 28). Similarly, the minimum seasonal fine root biomass ranged from 168 ± 1.7 g /m^2 at 1.0 m distance to 390 ± 4.4 g /m^2 at 1.5 m distance. Further, the mean FRB varied from 317 g /m^2 at 3.0 m to 484 g /m^2 at 1.5 m from stem base. Thus, around 55% of the FRB confined upto 1.5 m distance from stem base. The fine root production were found out to be 561 g /m^2/year at 0.5 m distance to 211 g /m^2/year at 3.0 m distance from stem base. Most of the fine root production layered towards near to stem base than farther. The fine root turnover rate though less than *Emblica officinalis* based AFS but recorded a value of 0.54 /year at 1.5 m distance from stem base to 1.21 /year at 0.5 m distance..

Table 27: Seasonal fine root biomass (mean± SD), mean FRB, annual fine root production and annual fine root turnover rate along 6 distances from stem base in 0-90 cm soil depth in *Emblica officinalis* based AFS

Distance from stem base	Seasonal fine root biomass (g/m^2)		Mean FRB (g m^2)	Production (g/m^2/yr)	Turnover rate (/yr)
	Maximum	Minimum			
0.5 m	152 + 2.6f	28 + 1.1b	76	124	1.63
1.0 m	121 + 2.9e	26 + 0.5b	80	95	1.18
1.5 m	93 + 2.0c	26 + 3.2b	66	68	1.03
2.0 m	85 + 1.1b	18 + 0.7a	53	68	1.28
2.5 m	105 + 0.7d	32 + 1.1c	61	74	1.21
3.0 m	79 + 2.6a	26 + 0.3b	44	53	1.20

Table 28: Seasonal fine root biomass (mean± SD), mean FRB, annual fine root production and annual fine root turnover rate along 6 distances from stem base in 0-90 cm soil depth in *Hardwickia binata* based AFS

Distance from stem base	Seasonal fine root biomass (g/m^2)		Mean FRB (g m^2)	Production (g/m^2/yr)	Turnover rate (/yr)
	Maximum	Minimum			
0.5 m	737 + 6.3	175 + 5.3	464	561	1.21
1.0 m	714 + 3.0	168 + 1.7	482	545	1.13
1.5 m	650 + 7.7	390 + 4.4	484	260	0.54
2.0 m	576 + 9.5	285 + 1.0	410	291	0.71
2.5 m	574 + 6.0	256 + 6.6	420	318	0.76
3.0 m	408 + 7.9	196 + 1.2	317	211	0.67

Technologies developed and transferred

Demonstrated the high density and agroforestry planting techniques on large scale of lemon, guava, karonda etc. on the farmer's field of DFI villages in Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot districts in DFI Project. Also, the boundary plantation of *Tectona grandis*, *Acacia senegal* were implemented in all the districts. Apart from this, laser levelling, field bunding, nutrient application strategies were demonstrated to the farmers of all the districts. Lectures were delivered to various stakeholders, including farmers, NGO's, field functionaries, about the agroforestry technologies, nutrient management, importance of soil health cards and popularize the institute technologies. Demonstrated soil health management strategies and method of soil sampling for development of soil health card during 5th December, 2019 on the occasion of World Soil Day. Delivered lectures and conducting practical's to the students of RLBCAU, Jhansi and B.Sc. (Forestry) students of College of Forestry, Dapoli about the nutrient cycling in agroforestry systems and its analysis at the laboratory.

NRMACAFRISIL 201900100117

Biomass modelling and area estimation in *Techtona grandis* based agroforestry systems in Central India

(S B Chavan, R H Rizvi, Asha Ram and R Vishnu)

Teak (*Tectona grandis* Linn. f.) is a large deciduous tree belongs to Lamiaceae family widely known as king of timbers and planted on seven lakh hectares in India. The species has been given major preference over other commercial tree species due to its resistance to various biotic and abiotic pressures, huge market demand; high quality timber and well developed market linkages. Being species from forest area, most of teak management techniques devised for as per the site quality, whereas growth is highly variable from teak grown in agricultural field. Under agroforestry, spacing, thinning, irrigation, pruning and fertilizer applications become possible factors to affect the wood volume and biomass production. Even though under recent climate change policies, reporting, motoring and verification of carbon become important aspect. By keeping in view, present study was designed to construct volume as well as biomass equations in central India.

The study was carried out by destructively harvesting of 34 teak trees from farmers as well as forest fields of Silwani, Raisen districts of Madhya Pradesh. Sampled trees were further separated, sorted, sub-sampled, dried to constant weight at 60°C and weighted for biomass components (only aboveground:-leaf, twig, branch & bole) (Plate 11). The DBH and tree height of felled trees was measured with the help of meter tape. The main bole was further divided in logs of 2-3 m length. The girth of log was measured at three points namely, lower, middle and top. The girth under bark (cm) of each log at centre was also recorded to develop volume equations.

The DBH of the harvested trees ranged from 14.94 to 38.42 cm and tree height of 11.2 to 19.00 m. The 34 trees were classified under six DBH classes (11-15, 16-20, 21-25, 26-30, 31-35 and 36-40) and presented growth parameters such as DBH, height, volumes, dry commercial bole weight and form factor in Table 29. The commercial volume of teak was estimated by using four traditional methods *viz*., Newton, Huber Smalian and quarter girth over bark gave an average volume of 0.337, 0.332, 0.346, 0.264 m^3/ tree, respectively. However, under bark volume by quarter girth formula was also estimated to develop volume equations. Among various formulae, newton's formula is the most accurate and it gives the volume not only of frustum of a neiloid correctly but also those of frustum of cylinder, paraboloid and cone. Though the accuracy of newton, Huber and Smalian volume estimation formula is high but quarter girth formula is widely used by foresters, wood traders and researchers due to

its ease in use. In the present study, quarter girth formula under-estimates tree volume by 28.17 %. In case of biomass estimation, average dry biomass and carbon stock of teak trees was 255.51 kg/tree and 127.5 kg/tree, respectively. Form factors are widely used in biomass as well as volume estimation of standing trees to achieve higher accuracies. It helps to reduce the error occurred during volume measurement of standing tree. The average form factor of teak was found to be 0.31 on diameter at breast height basis. The percent contribution of aboveground biomass was found maximum in bole (91.09 %) and this is due to periodical pruning of teak branches for knot-free timber (Fig. 12). Under modeling analysis, diameter at breast height (DBH) alone was found to be a very good predictor of commercial volume over other independent predictors such as height alone, product of DBH & height i.e. D^2H, logarithm of DBH and height. To get an idea of the shape of the function to be fitted on the data, a scatter plot of volume (ub) against dbh was drawn initially (Fig. 13). It was clear from scatter plot those non-linear functions (allometric, logistic, gompertz, gaussian and chapmans) to be better choice for predicting volume equations. Based on model selection criteria, six models predict volume considerably equal to observed volume. The adjusted R^2 (obs. vs pred.) values ranging from 0.92 to 0.94 for all the six models implying that all models are apparently equally efficient to predict volume (Table 30; Fig. 14). The linear model is easiest to fit and use, but it predicts native volume data, so it cannot be used. The mean absolute percent error (MAPE) was recorded highest for allometry function, where as lowest (11.70%) for chapman function.

During field survey, various teak plantations on farmer's field as well as forest department are visited and interacted. In case of farmer's field, dense block plantations of teak (2m×2m) was planted under different scheme such as "Lokvaniki" of Madhya Pradesh and the by private nursery growers. Following observation on growth of teak under block plantations are recorded as: 1) Uneven, crooked, poor, forked growth of teak trees due to planting at very closer spacing; 2) Tree management techniques such as thinning and pruning are not carried out in plantation; 3) the dead, diseased and dying trees are not removed to create healthy atmosphere in the plantation, 4) absence of timely fertilizer and irrigation scheduling. However some farmers are having well-managed teak based agroforestry models with intensive care (Plate 12). Timber depot of Forest Department at Raisen division was visited to collect information of sorting of girth-wise logs, management measures to avoid splitting and insect attacking of logs, auctioning of logs, price fixation process etc. (Plate 13). Apart from these, local carpenter industry also visited to gather information on supply chain, sale of logs, waste occurred during conversion of logs, various items of teak and their marketing.

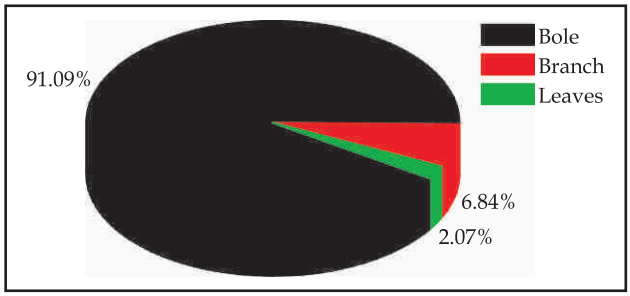


Fig. 12: Partitioning of above ground biomass (%) in *Tectona grandis*

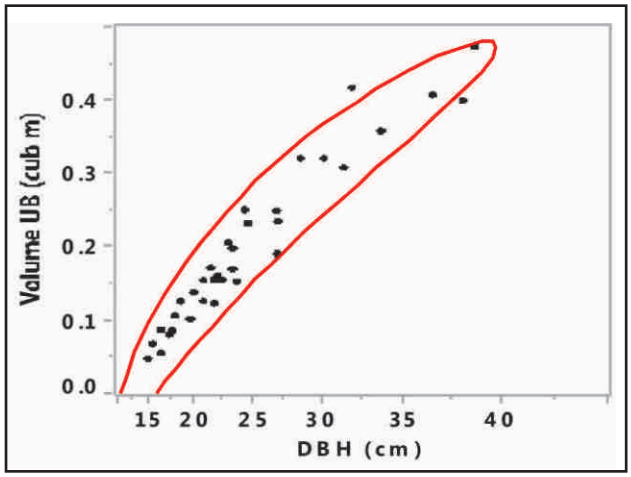


Fig. 13: Scattered plot of DBH (cm) - Volume (UB)

Table 29: Growth parameters, commercial volume and dry biomass of teak plantations at Silwani, Madhya Pradesh

DBHclass	Height	DBH	Commercial Volume (m^3/tree)					Dry weight (kg/tree)	Form factor
			Newton	Huber	Smalian	QG(OB)	QG(UB)		
11-15cm	11.65	15.27	0.092	0.091	0.094	0.072	0.057	89.45	0.32
16-20cm	12.76	18.14	0.147	0.147	0.149	0.117	0.096	98.47	0.36
21-25cm	14.70	22.76	0.266	0.262	0.274	0.208	0.172	187.94	0.35
26-30cm	15.72	27.99	0.389	0.391	0.387	0.311	0.262	269.60	0.32
31-35cm	17.70	32.41	0.530	0.524	0.543	0.416	0.360	387.07	0.28
36-40cm	18.23	37.86	0.595	0.579	0.626	0.460	0.425	500.53	0.25
Average	15.13	25.74	0.337	0.332	0.346	0.264	0.228	255.51	0.31
SED	2.63	8.63	0.20	0.20	0.21	0.16	0.15	163.92	0.04

Table 30: Parameter estimates of various functions fitted to merchantable volume of eucalypts (clubbed data)

S.No.	Models	Functional form	Parameter	Estimate	ASE	AICc	RMSE	Fratio	MAPE	R^2
1	Allometric	V=a×Xb	a	0.0004	0.0001	-231.12	0.0302	901.32	15.00	0.9242
			b	1.9368	0.1011					
2	Logistic	V=a/(1+exp(-(X-c)/b))	a	0.4934	0.0395	-238.14	0.0263	775.30	12.10	0.942
			b	5.9645	0.6976					
			c	26.7316	1.2220					
3	Chapman	V=a×(1-exp(-b×X))ca		0.6644	0.1378	-237.89	0.0263	769.69	11.70	0.9415
			b	0.0708	0.0198					
			c	6.0733	2.1428					
4	Gompertz	V=a×exp(-exp(-(X-c)/b))	a	0.6177	0.0938	-238.06	0.0263	773.49	11.80	0.9418
			b	11.8755	2.2024					
			c	25.7317	2.0654					
5	Linear	V=a+b×X	a	-0.2179	0.0189	-238.72	0.0270	521.13	12.20	0.9403
			b	0.0173	0.0008					
6	Gaussian	V=a*exp(-0.5*((X-c)/b)2)	a	0.4380	0.0259	-237.95	0.0263	267.12	12.20	0.9416
			b	12.8677	1.2059					
			c	40.6076	2.1112					

X=Diameteratbreastheight,MAPE:MeanAbsolutePercenterrorin%

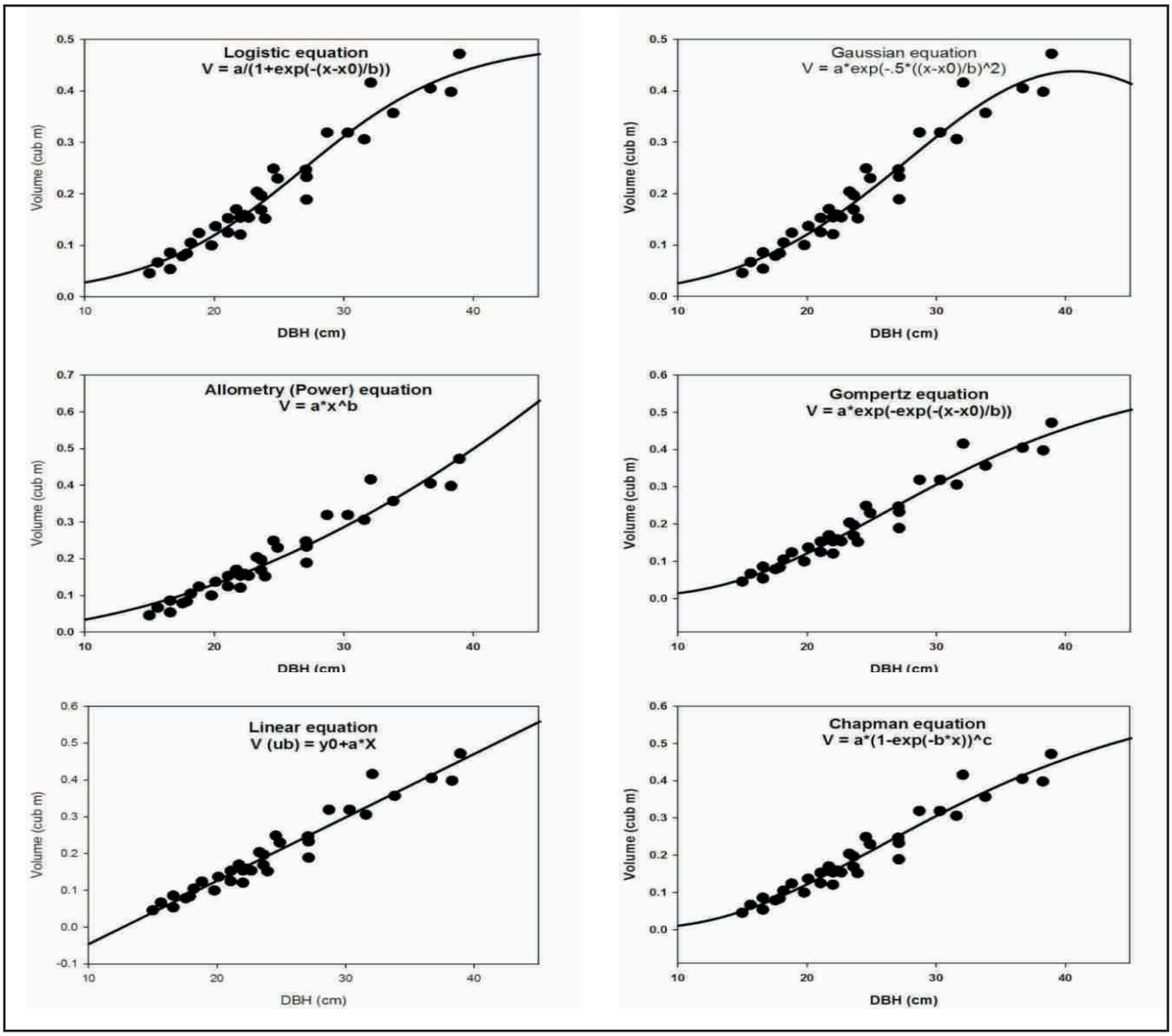


Fig. 14: Curvefiton various linear and non-linear functions

Plate 11: View of destructive sampling of *tectona grandis* trees at Solwani, Madhya Pradesh

Plate 12: Um-managed teak plantation at farmer's field in Madhya Pradesh

Plate 13: Intercropping of flowers under teak based agroforestry at farmer's field in Jhansi

Plate 14: View of timber depot and furniture articles in Silwani of Madhya Pradesh

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.3: Tree Improvement, Post-Harvest and Value Addition Programme

NRMACAFRISIL200700400071

Comparative studies on seedling and clonal plants of *Pongamia pinnata* with special reference to their adaptability to rainfed dry agroclimate

(Badre Alam, A K Handa, Sukumar Taria, Hirdayesh Anuragi and Alka Bharti)

Differential responses were observed in clonal and seedling plants in field with reference to their physiological performance. During peak summer conditions, clonal plants comparatively revealed better physiological efficiency than seedling plants. For example, the rate of CO_2 assimilation (P_N max), thylakoid electron transport rate (ETR) and effective quantum yield of photosystem-2 were relatively higher in clonal plants (Figs. 15, 16 & 17). This highly indicated in its relatively higher capacity to maintain photochemical efficiency during dry hot summer in clonal plants.

The differential physiological responses have been reflected in growth, pod formation and pod yield (Figs. 18 & 19) in clonal and seedling plants indicating better physiological efficiency of clonal plants. Indications were also noted in differential responses in water relation traits in leaves. Diurnal pattern of leaf water potential in peak summer revealed that leaf water relation trend in clonal plants indicated comparatively better drought adaptability in clonal plants than seedlings (Fig.20). During post-monsoon season, there was marginal difference in photochemical efficiency traits in clonal and seedling plants.

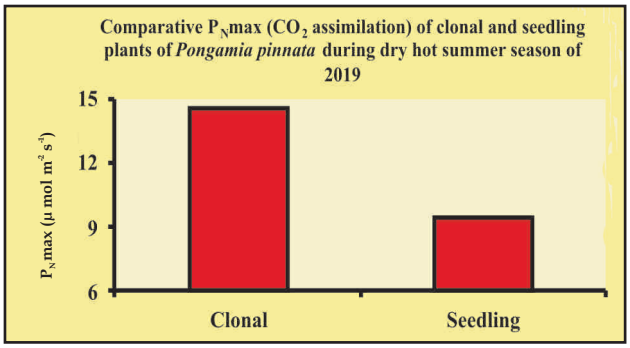


Fig.15: Maximum rate of CO_2 assimilation (P_N max) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

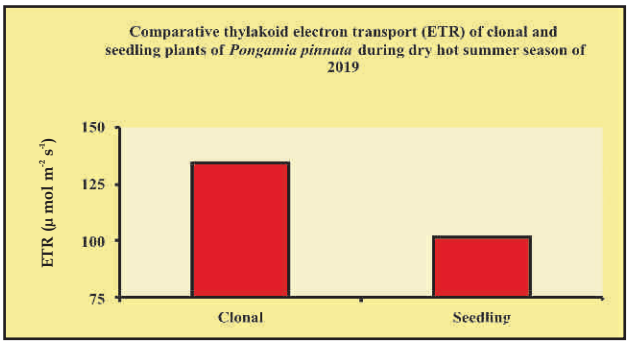


Fig. 16: Thylakoid electron transport rate (ETR) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

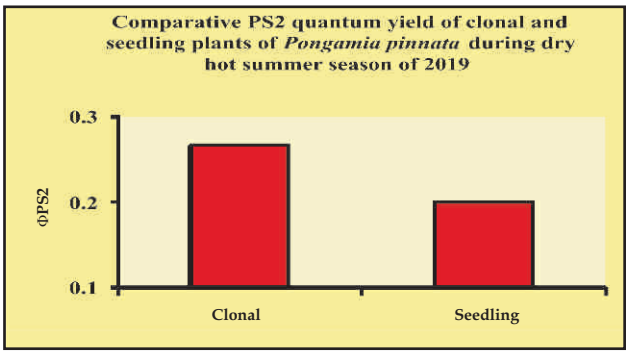


Fig.17: Effective quantum yield of PS2 of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

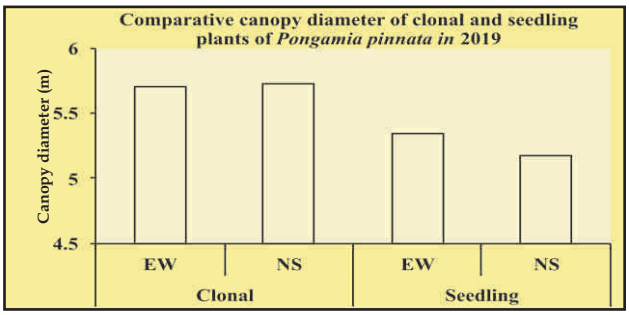


Fig. 18: Canopy diameter of clonal and seedling plants of *Pongamia pinnata* in east-west and north-south directions

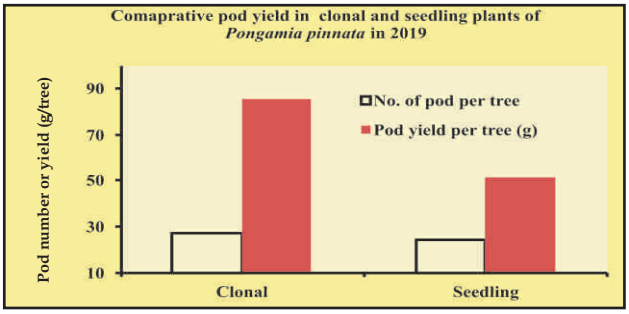


Fig. 19: Number of pods and pod weight per plant in clonal and seedling plants of *Pongamia pinnata*

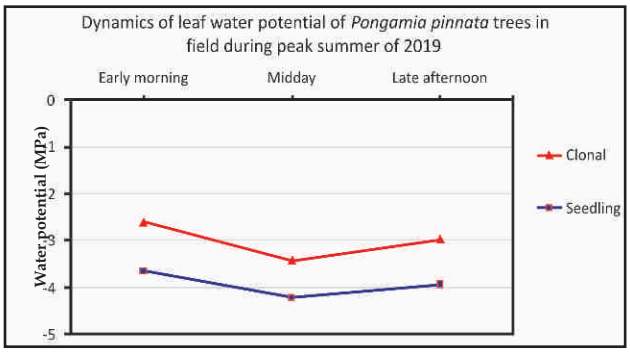


Fig. 20: Diurnal leaf water potential of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

NRMACAFRISIL201500100092

Evaluation and characterization of different Leucaena germplasm at ICAR-CAFRI

(K Rajarajan, A K Handa, A K Singh (IGFRI), Maneet Rana (IGFRI) and S B Chavan)

In the proposed year we have standardized high throughput DNA isolation protocol for *Leucaena* species. Further, in continuation with this a total of 519 SSR primers were used for marker analysis, in which 21 primers were selected based on reproducible amplified fragments under optimal conditions. Among 21 primers, 11 were found highly polymorphic nature and used to analyze the genetic diversity of 34 *Leucaena* germplasm (Fig. 21). Each experiment was performed at least twice. The 11 SSR primer amplified a total of 77 amplicon with an average of 7 alleles per locus. Size of alleles varied from 100 to 800 bp. Primer pair AnMtS13 amplified a maximum of 17 alleles, whereas LG100 amplified only 2 alleles. Further, similarity coefficient among34 Leucaena accessions was estimated by Jaccard's coefficient using NTSYSpc ver. 2.02h. The similarity coefficient ranged from 0.23 to 0.76 and indicated that substantial diversity among germplasms. Maximum similarity coefficient of 0.76 was observed between (*L. Leucocephala* S4 and *L. diversifolia*-504) & (*L. diversifolia*-46/87 and *L. diversifolia-83*) and minimum of 0.23 was observed between *L. Leucocephala* K-8 & *L. Leucocephala* S-22. Further, the cluster analysis revealed that 34 *Leucaena* accessions were broadly grouped into three major clusters comprising of 17 (Cluster I), 7 (Cluster II) and 10 (Cluster III) accessions, respectively on each clusters. With this the present study concluded that, substantial genetic diversity was existed among Leucaena germplasms and those highly diversified germpalsms can be used as donor parents for effective trait improvement through tree breeding.

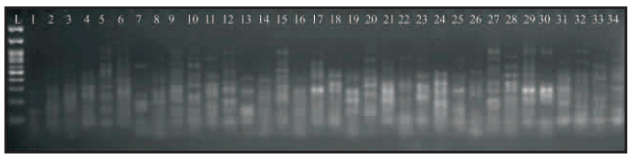


Fig. 21: Amplification profile of SSR 723 among 34 Leucaena genotypes

NRMACAFRISIL201600900107

TBOs based agroforestry models

(K B Sridhar, Inder Dev and R Vishnu)

To demonstrate and promote TBO based agroforestry model, an experiment was laid out at the experimental farm of ICAR-CAFRI, Jhansi. Trees selected for the study are *Pongamia pinnata*, *Simarouba glauca* and *Azadirachta indica*. Development of irregular flowers were observed

Plate 15: Pruning in *Pongamia pinnata*

in *Pongamia pinnata* and *Azadirachta indica*. The average height and collar diameter of trees was found to be highest in *Azadirachta indica* (4.84 m and 13.98 cm) followed by *Pongamia pinnata* (3.23 m and 8.69 cm) (Table 31). The castor crop was completely damaged due to flash floods during September 2018. The castor crop was unable to tolerate water stagnation for 15–20 days.

Table 31: The growth performance of TBO trees.

Species	Avg. Height (m)	Avg. Collar Diameter (cm)	Maximum height (m)	Maximum Collar Diameter (cm)
Azadirachta indica	4.84	13.98	5.96	18.15
Pongamia pinnata	3.23	8.69	4.50	12.74
Simarouba glauca	2.43	8.51	3.53	12.74

(*Dr. K.B. Sridhar transferred to ICAR-CRIDA, Hyderabad on 30th November, 2019)

NRMACAFRISIL201801100114

Functional genomics for early drought tolerance in *Pongamia pinnata* genotypes

(K Rajarajan, A Radhakrishnan, K B Sridhar, Lal Chand, Sukumar Taria, Hirdayesh Anuragi and Alka Bharti)

Functional genomics for early drought tolerance of *Pongamia pinnata* genotypes was initiated in the year of 2018. The aim of the present study is to assess an array of pongamia genotypes for its genetic variability and understanding the biochemical, physiological and molecular responses for drought tolerance. This study comprised of eighteen genotypes raised in standard size polybags in tree improvement nursery. During the proposed year genetic variability of eighteen pongamia genotypes were studied in two different seasons as summer and post rainy under two different ecosystem as optimum moisture and drought stress condition. The traits were considered *viz.* plant height (PHT), chlorophyll content (CHP), relative water content (RWC), excised leaf water loss (ELWL), proline content (PRL), root length (RL) and dry root weight (DRW). The traits *viz.*, RWC, ELWL and PRL were studied only under drought stress condition. In both the seasons under optimum moisture and drought stress condition the phenotypic co-efficient of variation (PCV) was higher than the genotypic co-efficient of variation (GCV) for all the morphological traits considered. It further indicated that substantial environmental influences over the traits. In both seasons under optimum moisture condition RL and DRW had higher heritability (h^2) and genetic advance as per cent mean (GAM). However, PHT had higher h^2 in summer season and found medium in post rainy season, whereas CHP had medium h^2 and GAM in both seasons under optimum moisture condition. In drought stress condition except PHT and CHP other traits *viz.*, RWC, PRL, ELWL, RL and DRW were showed higher h^2 and GAM in both seasons. Hence, performing early selection based on those traits had higher heritability coupled with GAM under drought stress condition can be useful for improvement of early drought tolerance of pongamia genotypes. Further, these eighteen genotypes were preliminarily screened into three early tolerant genotypes (2, 13 and 17) and early susceptible genotypes (3, 8 and 1) in both the seasons based on per cent reduction and mean performance (Fig. 22 & 23) of putative traits. These genotypes will be considered for further physiological and biochemical characterization.

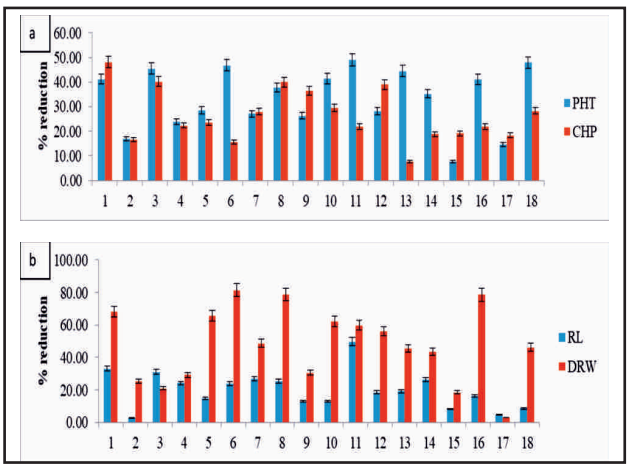


Fig. 22: Percent reduction of 18 pongamia genotypes for a; chlorophyll content and plant height b; dry root weight and root length, during summer 2019

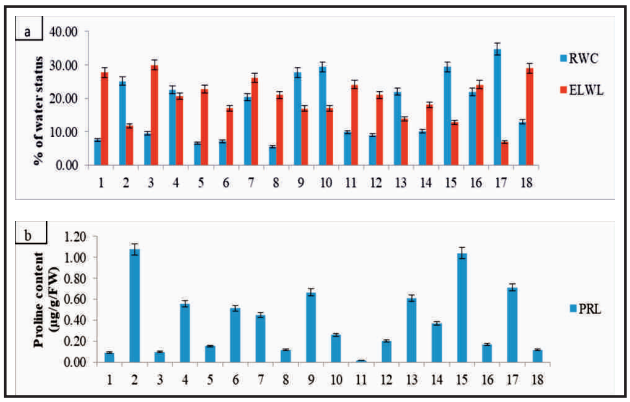


Fig. 23: Mean performance of 18 pongamia genotypes under drought stress condition during summer 2019 a; relative water content and excised leaf water loss b; proline content

NRMACAFRISIL201900200118

Collection, evaluation and hybridization of Moringa germplasms

(Hirdayesh Anuragi, Lal Chand, S B Chavan, Sukumar Taria, K Rajarajan, Alka Bharati and Y N Venkatesh)

Moringa oleifera, popularly known as drumstick or sahjan, has been referred as '*superfood*', '*miracle tree*' and '*tree of life*' owing to its extremely high nutritive and medicinal values having potential of curing more than 300 diseases. Moringa has Indian origin but grown worldwide with a huge demand for its leaves, pods and flowers. It is a handsome softwood tree signifies its importance attributable to very fast growing, high drought and temperature tolerance behavior which are important criteria in context to the challenge of present climate change scenario. Looking at the importance of moringa, the current proposal was planned with the ultimate objective of developing a mini-core collection of moringa at ICAR CAFRI, Jhansi and then identifying the superior quality genotypes with round the year fruiting habit along with their suitability in agroforestry for water scarce and hot Bundelkhand region. As a part of this, the activities for exploration and germplasm collection have been planned and will be carried out during the season of its fruiting stage.

OTHER RESEARCH ACHIEVEMENTS

(A) Evaluation of Bael (*Aegle marmelos* (L.) Corr.) Varieties under Semi-Arid Conditions of Bundelkhand

(Lal Chand, Sudhir Kumar, Asha Ram and Anil Kumar)

A varietal evaluation block of Bael [*Aegle marmelos* (L.) Correa] was established during July-August, 2018 at Experimental farm of ICAR-CAFRI, Jhansi, with the objective to evaluate six bael varieties (CISH-B-1, CISH-B-2, NB-5, NB-9, Kagzi Etawah and Goma Yashi) under edaphoclimatic conditions of Bundelkhand and find out suitable variety for Bundelkhand region. The block was established in randomized block design with three replication and three plant per replication at a spacing of 6 x 6m. The initial plant survival was recorded from 90 to 100 percent among different varieties. The initial growth performance of Bael varieties is given in Table 32. There is no clear growth trend has been observed among Bael varieties.

Table 32: Initial performance of Bael varieties under Jhansi conditions

Varieties	Survival (%)	Collar diameter (mm)	Trunk diameter (mm)	Plant height (cm)
CISH-B-1	100.0	19.0	13.0	90.8
Goma Yashi	88.9	23.5	15.8	104.6
Kagzi Etawah	88.9	27.3	18.3	93.6
CISH-B-2	100.0	28.1	18.4	116.5
NB-5	88.9	26.3	20.1	102.5
NB-9	87.5	16.5	11.9	64.2
Mean	92.4	23.4	16.2	95.4
SD	5.4	4.3	3.0	16.2
CV	5.9	18.6	18.4	17.0

(B) Production of planting material of Agroforestry species at Hi-tech Nursery

(S B Chavan and R Vishnu)

The Hi-tech nursery of the institute is engaged in production of quality planting material of agroforestry species. Presently nursery consists of approximately 15,000 seedlings of various tree species. Table 33 provides the available planting material in the nursery. The QPM of agroforestry tree species is provided to the farmers regularly. Apart from production of seedlings, mother hedge garden (MHG) of *Tectona garndis*, *Melia dubia*, *Melia azadirech*, *Eucalytpus tereticornis*, *Santalum album*, *Ailanthus excelsa*, *Gmelina arborea*, *Dalbergia latifolia*, *Swetennia mahogany* and *Psidium guajava* are developed under shade-net nursery by planting ten seedlings of each. The MHG is supplied with balanced fertigation (1 g All mix 20:20:20 + Calcium nitrate 0.5 g per seedling @ every 15 days) to obtain healthy planting material i.e. mini-nodal explants on monthly basis. Preliminary observations on success of teak mini-nodal techniques is reported @ 6000 ppm of IBA (Plate 16).

Table 33 : Available quality planting material in nursery

Sr. No.	Name of nursery stock	Number	Propagation
1	*Bambus vagaries* (green)	2000	cutting
2	*Eucalyptus tereticornis*	1200	Mini-nodal cutting
3	*Casuarina equisetifolia*	400	Mini-nodal cutting
4	*Melia dubia*	30	Mini-nodal cutting
5	*Tectona grandis*	100	Seed
6	*Pongamia pinnata*	2000	Seed
7	*Semaruba gluaca*	750	Seed
8	*Madhuca latifolia*	450	Seed
10	*Swietenia mahogany*	70	Seed
11	*Tamarindus india*	100	Seed
12	*Aegle marmelos*	200	Budding
	Emblica officinalis	100	Budding
	Poplar	200	Cutting

Plate 16: Glimpses of mini-nodal technique in *Melia dubia* & *Tectona grandis*

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.4: HRD, Technology Transfer & Refinement Programme

NRMACAFRISIL201500200093

Socio-economic, energetic and environmental impact assessment of watershed and agroforestry interventions at Garhkundar-Dabar watershed in Tikamgarh district of Madhya Pradesh

(R P Dwivedi, R K Tewari, Ramesh Singh, R H Rizvi and Mahendra Singh)

The data were collected from targeted villages. The details are given below:

In village Dabar, about 51% required fuelwood is collected from adjacent forest areas. The available tree species are Babul, Butea and Ber. The consumption of fuelwood is 5.5 Kg/day during rainy, 6 Kg/day during winter and 3.5 Kg/day during summer season. Cow & Buffalo dung is also used @ 5-6 Kg/day as per requirement. There are about 20-25 LPG connection under Pradhan Mantri Ujjwala Yojana (PMUY) in the village. Only 65% women do the collection of fuel wood.

In village Rautiana 68% of required fuel wood is collected from adjacent forest areas. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuel wood is 5 Kg/day during rainy, 7 Kg/day during winter and 4 Kg/day during summer season. It is found that the collection of fuel wood is being performed mostly by women (85%). Cow & Buffalo dung cake is another important fuel being used for cooking. The amount is 5 to 6 kg/day as per requirement. There are 15-20 LPG cylinders under PMUY in the village.

In village Kundar 43% of required fuel wood is collected from adjacent forest areas. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuelwood is 3 Kg/day during rainy, 4 Kg/day during winter and 3 Kg/day during summer season. It is found that the collection of fuel wood is being performed mostly by women (70%). Cow & Buffalo dung cake is another important fuel being used for cooking. The amount is 4 to 6 kg/day as per requirement. There are 50-60 LPG cylinders under PMUY in the village.

In village Sakuli, about 54% required fuel wood is collected from adjacent forest areas. The available tree species are Butea, Neem, Kardhai, Babul, Chirol and Akola. The consumption of fuelwood is 5.5 Kg/day during rainy, 7 Kg/day during winter and 3.5 Kg/day during summer season. Cow & Buffalo dung is also used @ 5-6 Kg/day as per requirement. There are about 100-110 LPG connection under PMUY in Sakuli. Only 45% women do the collection of fuel wood.

In village Shivrampur 79% required fuel wood is collected from adjacent forest areas. The available tree species are Butea, Kardhai and Besaram. The consumption of fuelwood is 7.5 Kg/day during rainy, 10.5-12.5 Kg/day during winter and 5.5 Kg/day during summer season. Cow & Buffalo dung is also used @ 5-6 Kg/day as per requirement. Average family size is 8 members in Shivrampur. There are about 30-35 LPG cylinders under PMUY in the village Shivrampur. In the village 92% women do the collection of fuelwood. Anna Pratha (stray animal) is a major constraint in adoption of agroforestry.

Kisan Gosthi, Farmers' Visits, Training and Exhibitions

The Institute organized a number of Farmers' activities for transfer of technologies of agroforestry and increase the awareness for speedy adoption of agroforestry during 2019. These are as below:

Inauguration of Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) Youjna

Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)Programme was directly telecasted at the Institute on 24th February,2019 for farmers of the

region. On this occasion, farmers were motivated for adopting the agroforestry for their livedoid.

Training Programme

A training programme on "Agroforestry Development" was organized for Farmers and Field officers from Jhansi, Mahoba and Chitrakut on 26th March, 2019. The training was sponsored by Uttar Pradesh Krishivaniki Mission, Lucknow (U.P.) and 56 farmers as well as field officers participated.

Farmer's Workshop

A Farmers' Workshop entitled "गुणवत्ता युक्त पौधों द्वारा बुन्देलखण्ड क्षेत्र में कृषिवानिकी का विस्तार" on 8th May, 2019 was also organized. The workshop

was organized in collaboration with World Agroforestry Centre, South Asia Regional Office, New Delhi, ICRISAT, Hyderabad, ICAR-CAFRI, Jhansi and ISAF, Jhansi. About 200 farmers from seven district of Bundelkhand region of Uttar Pradesh participated in the workshop.

Exposure visit of ICRAF-Odisha stakeholders

ICAR-CAFRI, Indian Society of Agroforestry and ICRAF, South Asia Office, New Delhi organised an exposure visit of ICRAF-Odisha stakeholders, which included the key nodal officers from line departments for Agroforestry & NRM activities during 28th -30th May, 2019 at ICAR-CAFRI, Jhansi. During the exposure visit interaction meeting with all the scientists and ICRAF-Odisha stakeholders took place. Field visits to Research Farm of ICAR-CAFRI, Parasai-Sindh and Garhkundar Dabar watershed were also organized during the exposure visit.

Farmers' Workshop

One day workshop on "World Day to Combat Desertification and Drought" was organized jointly by ICAR-CAFRI, Jhansi, ICRISAT-Hyderabad, ICAR-IGFRI, Jhansi and Forest Department, Lucknow, Uttar Pradesh at Central Agroforestry Research Institute, Jhansi on 17th June, 2019. Presentation on different aspects like interventions by Forest Department towards addressing desertification and drought in Bundelkhand, importance of soil and water conservation measures in relation to DFI and to combat desertification and drought, agroforestry for diversification and sustainable yield, grassland production and management in non-arable lands and overview of different activities undertaken by ICAR-CAFRI, Jhansi etc. were made. About 120 participants from Bundelkhand region including farmers participated in this workshop.

Training of ICRAF-Odisha Farmers

-ICAR-CAFRI, Indian Society of Agroforestry and ICRAF, South Asia Office, New Delhi organized a training of ICRAF-Odisha farmers (Nuapada and Bolangir districts) and ICRAF Odisha staff for Agroforestry & NRM activities in ICAR-CAFRI during 20th -24th September, 2019 (five days) at ICAR-CAFRI, Jhansi. Eleven farmers and 02 project staff participated.

Ber Pruning and Budding Training

Institute organized three days' "ber pruning" training during 11th -13th June, 2019 at Village-Dhikoli, Block-Babina, District-Jhansi (U.P.). In this training programme 30 farmers learned the skills of ber pruning.

Institute also organized three days' "ber budding" training during 20th – 22nd July, 2019 and 17th August,2019 at Village- Dhikoli, Block-Babina, District-Jhansi (U.P.). In this training programme 26 farmers learned the skills of budding.

Exhibitions

ICAR-Central Agroforestry Research Institute, Jhansi participated in following different exhibitions during the year-2019 and showcased the technology developed by the Institute through exhibitions:

Date	Programme	Places
9th -11th February, 2019	Krishi Kumbh	Motihari (Bihar)
25th February,2019	Kisan Mela	ICAR-IGFRI, Jhansi
28th February,2019	Kisan Mela	KVK Bharari, Jhansi
8th May, 2019	Kisan Mela and Krishak Karyashala	ICAR-CAFRI,Jhansi (U.P.)
25th October,2019	National workshop on DFI RLBCAU, Jhansi(U.P.)	

MERA GAON-MERA GARAUV (MGMG)

The plantation drive in the MGMG villages was carried out by Scientists of ICAR-CAFRI Jhansi in the selected MGMG villages. The scientists also interacted and created awareness about Agroforestry among the farmers. Organized interface meetings with the farmers of MGMG villages during 2019. Total 5350 plants were distributed to the farmers till December, 2019. The list of clusters (5) and villages (16) are as below:

1. Hastinapur cluster (3 villages- Hastinapur, Karari, Rund Karari). U.P.
2. Domagor cluster (3 villages-Domagor, Dhikoli, Nayakhers). U.P.
3. Ganeshgarh cluster (3 villages- Ganeshgarh, Devgarh, Ramgarh). U.P.
4. Parasai cluster (3 villages- Parasai, Chhatpur, Bachhauni) U.P.
5. Garhkundar cluster (4 villages- Garhkundar, Dabar, Sakuli, Shivrampur) (M.P.)

Visits

A number of students and Govt./NGOs officers from different parts of the country, Officials from Forest Department, University sudents and State department official of different parts of the country and Bundelkhand region visited the Institute and demonstration sites. During the year a number of farmers from M.P., U.P. and Rajasthan visited the Institute as per the following details:

Date	No. of Farmers & Place	Date	No. of Farmers & Place Place
22.01.2019	77 farmers from Vidisha & Jabalpur (M.P.)	31.08.2019	21 farmers from Datia (M.P.)
01.02.2019	40 farmers from Datia (M.P.)	05.09.2019	24 farmers from Damoh (M.P.)
04.02.2019	07 students from Bundelkhand University, Jhansi (U.P.)	07.09.2019	24 farmers from Guna (M.P.)
25.04.2019	02 farmers Garotha, district Jhansi (U.P.)	16.09.2019	87 forest department Shivpuri & Chhatarpur (M.P.)
08.05.2019	116 framers CAFRI Jhansi on foundation day & workshop	10.10.2019	12 from Tikamgarh (M.P.)
13.05.2019	01 farmer from Hapur (U.P.)	16.10.2019	26 farmers from Guna (M.P.)
01.06.2019	01 NGO- Satyavati Seva Sansthan on from Lalitpur, (U.P.)	17.10.2019	26 Foreigners (Asia-Africa)
14.06.2019	01 Farmer on from Ambavay district Jhansi(U.P.)	22.10.2019 & 07.11.2029	98 farmers from Raisen (M.P.)
03.07.2019	35 staff of Telangana State Forest Academy, Hyderabad	14.11.2019	44 students Dr. S. Radha Krishan Public Inter college, Jhansi (U.P.)
12.07.2019	02 farmers from village Dhikoli district Jhansi (U.P.)	19.11.2019	12 M.Sc. & Ph.D. students from NDRI, Karnal (H.R.)
24.07.2019	30 farmers from Bharatpur (Rajasthan)	07.12.2019	20 farmers from Guna (M.P.)
24.07.2019	82 farmers from Damoh (M.P.)	23.11.2019, 02.12.2019, 03.12.2019 & 27.12.2019	81 farmers from Gwalior (M.P.)
20.08.2019	16 farmers from Chhatarpur (M.P.)	17.12.2019	25 farmers from Dabra, Gwalior (M.P.)

Schedule Caste Sub Plan (SCSP)

The SCSP programme is being implemented with the objective of on farm technologies demonstrations on different aspects of agroforestry with emphasis on plantation of fruit trees as well as MPTs, skill development and capacity building as per the following details:

In the Schedule Caste Sub Plan (SCSP) programme in all the 7 districts (Lalitpur, Jhansi, Jalaun, Hamirpur, Mahoba, Banda and Chitrakoot) of Bundelkhand U P about 85706 saplings of guava moringa, custard apple, lime, mango, pomegranate, fig, aonla, jack fruit, bamboo, mahua, *Acacia senegal* and teak were distributed for plantation. In this plantation for agroforestry 450 families of SC community were benefitted.

On 8th May 2019, Farmers' workshop on quality planting material was organized in which the SC farmers were also benefited.

CHAPTER 2

RESEARCH ACHIEVEMENTS

2.5: Externally Funded Projects

Network Project

NRMACAFRISOP200800100075

Harvest and post-harvest processing and value addition of natural resins, gums and gum resins

(Rajendra Prasad, A K Handa, Ramesh Singh and Badre Alam)

ICAR-CAFRIMandate:*"Development of agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies"*

The main objective of the project is to develop agroforestry models including resins- and gum-yielding trees for livelihood security and horizontal dissemination of technologies. For conducting research at ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi, the major themes are i) growth and productivity of gum-yielding tree-based agroforestry models, ii) demonstration and development of gum-yielding tree-based agroforestry models on farmers' fields, and iii) indigenous traditional knowledge (ITK) on resin and gum tapping, applications and post harvest value addition. During the year, growth and productivity data of established gum-yielding tree-based agroforestry models were recorded and farmers of nearby villages were motivated to plant agroforestry models on their farms. Studies on biomass, carbon stock and carbon sequestration rate in *Acacia senegal* and *Acacia nilotica* planted in a *rainfed* agri-silviculture model was conducted. Apart from this, economic analysis of a ten years old agri-horti-silviculture model established at research farm of the institute was conducted and study on effect of soil moisture content on natural oozing of gums from *A. senegal* and *A. nilotica* initiated.

A. GROWTH AND PRODUCTIVITY OF AGROFORESTRY MODELS

A.1. Agroforestry models on-farm

Data on survival and growth of trees planted in various agroforestry models established at central research farm of the institute are presented in Table 34.In agri-horti-silviculture model (field no. 25), maximum GBH (cm), plant height (cm) and canopy spread (m^2) were recorded in *Aegle marmelos* (bael), followed by *A. senegal*(kumat), *Citrus limon* (lemon) and *Carissa carandas* (karonda). Since, casualty replacement was done during 2018-19; hence, maximum survival (%) was recorded in *C. carandas*, followed by *A. senegal*, *C. limon* and *A. marmelos* (Table 34). Pruning of tree's crown was carried out in the month of October i.e. before sowingof winter crops. In this model, fruit yields were recorded from 14 plants of *C. limon*, 19 plants of *A. marmelos* and 16 plants of *C. carandas* (Plate 17). A total of 71.00 kg lemon, 70.40 kg karonda and 1018.00 kg bael fruits were harvested. The average weight of bael variety CISH B1 was 0.70 kg and variety CISH B2 was 1.40 kg. During *rabi* (2018-19) and *kharif* (2019), wheat (variety HD 2967) and moong (variety IPM 0214), respectively were cultivated as intercrops in the model. This year i.e. 2019-20 (*rabi* season), wheat (variety HD 2967) was sown. During 2018-19, natural oozing of gum (average 16.37 g/tree from 5 trees) from *A. senegal* was recorded.

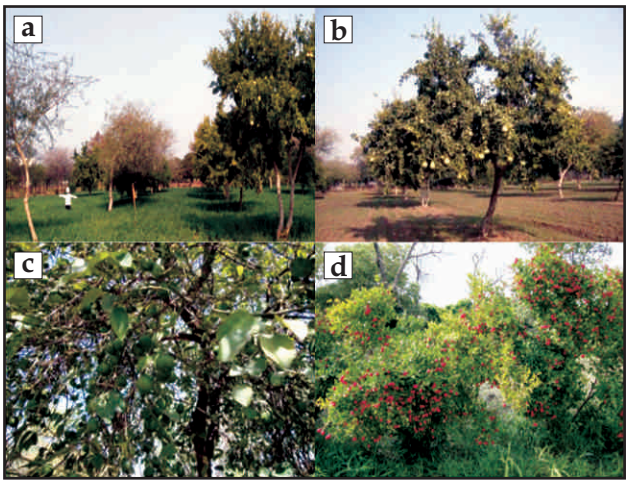


Plate 17:*Acacia senegal* **based agri-horti-silviculture model at research farm of ICAR-CAFRI, Jhansi. A- Wheat, B-** ***Aegle marmelos*****, C-** ***Citrus limon*** **and D-** ***Carissa carandas***

In horti-silviculture model I (field no. 20), *Terminalia arjuna* (arjun) showed maximum survival (100%), followed by *A. senegal* and *Acacia nilotica* (babool). Growth parameters i.e. GBH (cm) and plant height (cm) were recorded maximum in *A. senegal*. In horti-silviculture model II (field no. 20), *T. arjuna* showed maximum survival (100%), followed by *A. nilotica* and *A. senegal*. Highest GBH, plant height and canopy spread were recorded in *A. nilotica*. Survival of *A. senegal* in block plantation on rocky site was found to be 100% and plants attained mean height of 479.7 cm with GBH of 23.7 cm (Table 34).

In *rainfed* agri-silviculture model (field no. 40 & 41) wherein *A. senegal* and *A. nilotica* were planted in three different spacings; maximum survival was recorded by *A. senegal* planted in 10 m × 10 m spacing while in case of *A. nilotica,* it was recorded highest in 5 m × 5 m spacing (Table 34). After seven years of plantation, higher GBH and plant height were recorded in *A. nilotica* than *A. senegal* in all spacings, barring few exceptions.

Table 34: Survival and growth of trees planted in various agroforestry models at ICAR-CAFRI, Jhansi

Agroforestry models	Survival (%)	GBH (cm)	Height (cm)	Canopy spread (m^2)	Pruned biomass (kg/tree)
Agri-horti-silviculture (field no. 25)					
Acacia senegal	92.9	37.6	524.0	24.2	13.52
Citrus limon	79.2	23.8	411.5	17.4	4.26
Aegle marmelos	78.6	40.3	556.4	31.9	5.74
Carissa carandas	93.5	3.87 (CD)	186.4	2.1	--
Horti-silviculture I (field no. 20)					
*Acacia nilotica**	53.6	34.5	546.3	22.4	18.18
Terminalia arjuna	100.0	30.5	515.3	8.5	30.61
Acacia senegal (at boundary)	90.0	41.6	578.0	14.1	14.16
Horti-silviculture II (field no. 20)					
Acacia nilotica	85.7	87.0	948.8	71.4	291.92
Terminalia arjuna	100.0	28.0	439.8	6.8	31.4
Acacia senegal (at boundary)	80.0	29.0	545.6	21.7	36.3
Block plantation					
Acacia senegal	100.0	23.7	479.7	11.7	--
Agri-silviculture (field no. 40 & 41) - 7 years old					
Acacia senegal					
10 m × 10 m	94.7	32.6	496.2	17.2	10.2
10 m × 5 m	83.3	22.6	422.7	14.7	8.00
5 m × 5 m	84.4	27.5	478.8	15.4	9.3
Acacia nilotica					
10 m × 10 m	71.4	31.5	465.7	14.0	3.1
10 m × 5 m	82.6	27.2	435.0	12.8	5.00
5 m × 5 m	89.9	30.4	495.6	13.3	5.92

** Plantation in 2014*

During summer season of year 2019, natural exudation of gum in different fields of *A. senegal* was observed (Table 35). Gum yield ranged from 1.33–66.39 g/tree in field no. 25 (average: 16.37 g from 5 trees), 1.51–110.0 g/tree in field no. 40 & 41 (average: 33.15 g from 21 trees), 1.23–112.70 g/tree in old gum garden (average: 30.62 g/tree from 31 trees), 1.29–102.29 g/tree in new gum garden (average: 19.24 g/tree from 23 trees) and 13.56–76.90 g/tree (average: 35.00 g/tree from 5 trees) in block plantation in rocky area. Maximum number of gum tears/tree (91) was recorded in old gum garden while minimum (13) was recorded in block plantation.

Table 35: Descriptive statistics of gum yield from *Acacia senegal* tree (natural exudation)

Particulars	Field no. 25		Field no. 40 & 41		Old gum garden		New gum garden		Block plantation	
	No. of tear/ tree	Gum yield (g/ tree)	No. of tear/ tree	Gum yield (g/ tree)	No. of tear/ tree	Gum yield (g/ tree)	No. of tear/ tree	Gum yield (g/ tree)	No. of tear/ tree	Gum yield (g/ tree)
Count	18	5	80	21	91	31	64	23	13	5
Mean	3.60	16.37	3.81	33.15	2.94	30.62	2.78	19.24	2.60	35.00
Min.	1.00	1.33	1.00	1.51	1.00	1.23	1.00	1.29	1.00	13.56
Max.	10.00	66.39	13.00	110.0	7.00	112.70	10.00	102.29	4.00	76.90
SD	1.63	12.55	0.75	7.63	0.31	5.46	0.53	4.78	0.51	11.02

Similarly, natural exudation of gum in different fields of *A. nilotica* was also observed (Table 36) and the gum yield ranged from 35.31–160.58 g/tree in field no. 20 (average: 112.15 g/tree from 5 trees) and 1.85–56.24 g/tree in field no. 40 & 41 (average: 12.55 g/tree from 25 trees).

Table 36: Descriptive statistics of gum yield from *Acacia nilotica* trees (natural exudation)

Particulars	Field no. 20		Field no. 40 & 41	
	No. of tear/tree	Gum yield (g/tree)	No. of tear/tree	Gum yield (g/tree)
Count	98	5.00	97.00	25.00
Mean	19.60	112.15	3.88	12.55
Min.	10.00	35.31	1.00	1.85
Max.	25.00	160.58	12.00	56.24
SD	2.82	21.64	0.60	2.56

During *rabi* season of 2018-19, wheat (variety HD 2967) was sown in agri-horti-silviculture model (field no. 25) and the recommended package of practices was followed. Plant growth and yield attributes of wheat were measured at three different distances *viz*., 1.0, 2.5 and 4.5 m from the stem base of *A. senegal*, *A. marmelos* and *C. limon*. Planted tree species significantly affected plant population, seed yield and above ground dry biomass. Maximum biomass was recorded under *C. limon* which was statistically at par with *A. senegal* (Table 37). Significantly higher yield was recorded under *A. senegal*. On the other hand, distance from tree trunk significantly affected all the recorded paramete` Plant population, seed yield and biomass were found to be increasing with increase in the distance from tree trunk i.e. their maximum values were recorded at 4.5 m and minimum at 1.0 m distance. Two-way interaction between tree species and distancewas found significant in case of seed yield and dry biomass. Maximum yield was recorded at 4.5 m distance under *A. senegal* which was at par with the yield recorded at 4.5 m distance in*C. limon*.

Table 37:Yield of wheat (variety HD 2967) under agri-horti-silviculture (2018-19)

Parameters	Distance (m)	Tree species			Mean
		Acacia senegal	*Citrus limon*	*Aegle marmelos*	
Plant population/m^2	1.0	37	43	39	40
	2.5	43	48	44	45
	4.5	55	61	54	56
	Mean	45	50	46	
Seed yield (g/m^2)	1.0	305.67	224.00	229.67	253.11
	2.5	398.00	308.00	289.00	331.67
	4.5	437.67	413.00	305.67	385.44
	Mean	380.44	315.00	274.79	
Above ground dry biomass (g/m^2)	1.0	785.00	605.00	506.00	632.00
	2.5	887.67	782.00	647.67	772.44
	4.5	961.00	1181.00	742.67	961.56
	Mean	877.89	865.00	632.11	
	Plant population	**Seed yield**	**Above ground dry biomass**		
Tree species	3.0	17.01	48.43		
Distance	3.0	17.01	48.43		
Tree species × distance	NS	29.46	83.88		

During *kharif* season of 2019, moong (variety IPM 0214) was sown in agri-horti-silviculture model (field no. 25) and the recommended package of practices was followed. Plant growth and yield attributes of moong were measured at three different distances *viz*., 1.0, 2.5 and 4.5 m from the stem base of *A. senegal*, *A. marmelos* and *C. limon*. Results revealed that tree species significantly affected the seed yield of moong. Maximum yield was recorded under *A. senegal*, followed by *C. limon* and *A. marmelos* (Table 38). Irrespective of plant species, distance from the tree trunk significantly affected all studied paramete` Maximum plant population, seed yield and above ground dry biomass were recorded at 4.5 m distance from the stem base and their minimum values were recorded at 1.0 m distance. The interaction between tree species and distance had no significant effect on plant population. Maximum yield was recorded at 4.5 m distance of *A. senegal* and minimum at 1.0 m distance from *A. marmelos*.

Table 38:Yield of moong (variety IPM 0214) under agri-horti-silviculture (2019)

Parameters	Distance (m)	Tree species			Mean
		Acacia senegal	*Citrus limon*	*Aegle marmelos*	
Plant population/m^2	1.0	10.0	14.7	13.7	12.8
	2.5	12.7	17.7	17.7	16.0
	4.5	15.0	18.7	20.0	17.9
	Mean	12.6	17.0	17.1	
Seed yield (g/m^2)	1.0	43.9	37.5	17.0	32.8
	2.5	56.1	53.0	18.1	42.4
	4.5	57.0	54.1	36.0	49.0
	Mean	52.3	48.2	23.7	

Table 38:Yield of moong (variety IPM 0214) under agri-horti-silviculture (2019)

Parameters	Distance (m)	Tree species			Mean
		Acacia senegal	*Citrus limon*	*Aegle marmelos*	
Plant population/m^2	1.0	10.0	14.7	13.7	12.8
	2.5	12.7	17.7	17.7	16.0
	4.5	15.0	18.7	20.0	17.9
	Mean	12.6	17.0	17.1	
Seed yield (g/m^2)	1.0	43.9	37.5	17.0	32.8

During *kharif,*2019, cultivation of intercrops commenced in *rainfed* agri-silviculture model, consisting of *A. senegal* and *A. nilotica* planted in three different spacing *i.e.* 10 m × 10 m, 10 m × 5 m and 5 m × 5 m (Plate 18). Moong (varety IPM 0214) was cultivated by adopting standard package of practices. To assess the effect of planting spacing, samples of understory crop were taken by qudrat (1 m × 1 m) method from all three spacing regimes. Observations on plant population, seed yield and above ground dry biomass were recorded. Wider spacing (10 m × 10 m) recorded maximum population, seed yield and dry biomass of moong and closer spacing (5 m × 5 m), the minimum (Table 39). On the other hand, tested tree species showed significant effect on plant population and seed yield. These were recorded significantly higher under *A. senegal* than *A. nilotica*. Tree species did not affect dry biomass. Two-way interaction between spacing and plant species was recorded significant for seed yield and dry biomass. Significantly higher seed yield was recorded from *A. senegal* planted in 10 m× 10 m spacing.

Plate 18: Cultivation of moong (variety IPM 0214) in *rainfed* agri-silviculture model (field no. 40 & 41)

Table 39:Yield of moong (variety IPM 0214) under *rainfed* agri-silviculture model during 2019

Parameters	Tree species	Spacing (m)			Mean
		10 × 10	10 × 5	5 × 5	
Plant population/m^2	*A. senegal*	13.7	11.3	10.0	11.7
	A. nilotica	9.3	8.7	7.3	8.4
	Mean	11.5	10.0	8.7	
Seed yield (g/m^2)	*A. senegal*	61.49	49.97	36.73	49.40
	A. nilotica	42.18	34.98	31.25	36.13
	Mean	51.83	42.47	33.99	
Above ground dry biomass (g/m^2)	*A. senegal*	178.3	157.7	137.3	157.8
	A. nilotica	187.3	154.7	130.7	157.6
	Mean	182.8	156.2	134.0	
	Plant population	**Seed yield**		**Above ground biomass**	
Spacing	1.6	2.83		5.56	
Tree species	1.6	2.83		NS	
Spacing × tree species	NS	4.91		9.64	

Gum garden

Survival (%) was higher in *A. senegal* than *B. monosperma* in both the gardens(Table 40). The planted saplings of *B. monosperma* showed very poor performance. *A. senegal*, planted in new gum garden *i.e.* during 2015, attained good girth and showing relatively higher survival (%) than the seedlings planted during 2014. Out of 190 plants of *A. senegal* raised in old gum garden (2014 plantation), 31 plants yielded *gum-arabic*. Similarly, out of 268 *A. senegal* planted in new gum garden (2015 plantation), natural exudation of *gum-arabic* was observed from 23 plants.

Table 40: Growth parameters of *Acacia senegal* and *Butea monosperma* in gum gardens

Tree species	Survival (%)	GBH (cm)	Height (cm)	Canopy spread (m^2)	Pruned biomass (kg/tree)
Gum garden part-I (Planted in July, 2014)					
Acacia senegal	73.7	17.6	374.6	10.8	6.40
Butea monosperma	43.3	7.2 (CD)	49.1	3.9	--
Gum garden part-II (Planted in July, 2015)					
Acacia senegal	93.9	14.2	356.4	9.31	4.52
Butea monosperma	58.3	0.99 (CD)	63.6	--	--

Growth of *Anogeissus pendula*

The growth of existing plantations of *Anogeissus pendula* (progeny trial), which is now being used for standardizing gum tapping techniques, was monitored during 2019-20. The plantation (September, 1994) is consisting of tissue culture raised progenies of five plus trees of *A. pendula* (kardhai), planted in randomized block design with four replications. Each progeny had 25 plants in a plot. Net plot size was 15 m × 10 m with the spacing of 3 m × 2 m. On an average, the recorded GBH (cm) of AP-12, AP-52, AP S-2, AP-28 and AP-35 progenies were 34.25, 34.12, 35.94, 34.02 and 35.22 cm, respectively. The maximum GBH was recorded in AP S-2 and minimum in AP-28 progeny (Fig.24A).

Growth of trees was also recorded in experimental field where in seven progenies of *A. pendula* (plus tree trial) raised through tissue culture were planted in August, 1995 along with local check in randomized block design in four replications having plot size of 15 m × 10 m with a spacing of 3 m × 2 m. Very slow growth in terms of GBH (cm) was reported during 2019-20. The GBH of AP-20, J-241, J-124, J-205, NRC-5, J-185 and J-62 progenies were 32.63, 32.44, 35.35, 40.59, 31.93, 37.60 and 38.31 cm, respectively. Maximum GBH was recorded in J-205 and minimum in NRC-5 progeny (Fig.24B).

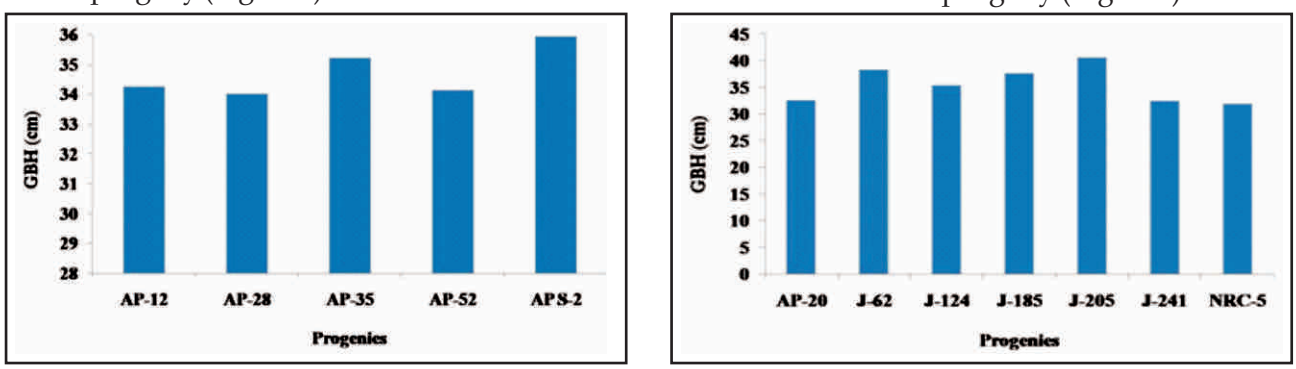


Fig. 24: GBH (cm) of different progenies of *Anogeissus pendula* after 25 years (A) and 24 years of plantation (B)

Growth of another plantation consisting of *A. pendula* and *Anogeissus latifolia* (dhawra) was also monitored (field no. 33 & 34). This plantation was established in 1990 which is now being used as agroforestry models for tapping gum and raising intercrops. The trees were planted at 5 m × 5 m spacing. The recorded growth increment was very negligible after 29 yea` The better survival (%) was recorded in *A. pendula* (87.5%) while, better GBH (cm), height (cm) and canopy spread (m^2) were recorded in *A. latifolia* (Table 41).

Table 41: Growth of *Anogeissus pendula* and *Anogeissus latifolia* after 29 years

Tree species	Survival (%)	GBH (cm)	Height (cm)	Canopy spread (m^2)
Anogeissus pendula	87.5	43.8	745.1	24.7
Anogeissus latifolia	82.4	45.8	779.7	26.3

A2. Agroforestry models on farmers' fields

After ten years of planting, *A. senegal* recorded relatively more survival (up to 59.5%) than *A. nilotica* (up to 50%) at Garhkundar watershed area. At the farm of Shri Thakur Das, among planted species, *A. nilotica* recorded higher growth as well as survival, followed by *Psidium guajava* (guava) and *C. carandas*. In this field, many plants have been damaged by mechanized operations with tractor, as the farmer did not pay attention. On the farm of Shri Himmat, maximum growth was recorded in *Emblica officinalis* (aonla); however, survival (%) was recorded comparatively higher in *A. senegal*. At the farm of Shri Ghanshyam, *A. senegal*planted during 2012 showed poor performance in terms of growth; however, survival (%) was comparatively higher than the values recorded from other two fields. At village Ambabai, 37% survival of *A. senegal* with average height of 280.5 cm and average collar diameter of 13.0 cm was recorded (Table 42).

Table 42: Growth of trees in agroforestry models at Garhkundar watershed (10 years old) and village Ambabai (7 years old)

Plant species	Survival (%)	GBH (cm)	Height (cm)	Canopy spread (m^2)
Shri Thakur Das				
Acacia nilotica	50.0	37.5	572.5	11.7
Psidium guajava	10.5	23.8	442.5	13.2
Carissa carandas	12.5	1.0 (CD)	145.0	0.6
Shri Himmat				
Acacia senegal	56.8	37.3	412.2	4.9
Emblica officinalis	51.2	58.7	524.7	21.7
Carrisa carandas	18.0	4.3 (CD)	152.0	0.3
Shri Ghanshyam				
Acacia senegal (boundary)*	59.5	14.1	197.4	--
Shri Mani Ram (village Ambabai)				
Acacia senegal	37.0	13.0	280.5	6.1

*Planted in 2012

B. DEMONSTRATION AND DEVELOPMENT OF GUM-YIELDING TREE-BASED AGROFORESTRY MODELS

B1. At institute research farm

During rainy season of 2018, four bio-fence models were planted at the institute's research farm. Casualty replacement was done during rainy season of 2019 in all models. Bio-fence model-1, aiming to optimize the distance apart *A. senegal* and *C. carandas* (1.0, 1.5 and 2.0 m apart), was maintained and observation on growth and survival was recorded. After 1.5 years of planting,

survival of *A. senegal* and *C. carandas* was 95.5 and 84.1%, respectively (Table 43).

Bio-fence model-2 aimed to assess effectiveness of double row fence consisting of *A. senegal* as outer row and *C. carandas* as inner row on field bunds. Distance between two rows was 1.0 m and within the row, plant to plant distance was 2.0 m. The planting of both species in two rows was done in staggered manner. After 1.5 years of planting, 86.7 and 92.6% survival of *A. senegal* and *C. carandas*, respectively were observed (Table 43).

Bio-fence model-3 aimed to assess the effectiveness of double row fence of *A. senegal* at different spacement. This model was planted on three sides of field boundary of a well-established *E. officinalis* orchard. Plant to plant distance was kept uniform at 1.5 m in both the tree rows, while the distance between two rows varied at all three sides of the field *i.e.* 1.0, 1.5 and 2.0 m. Planting was done in staggered manner in two rows. After 1.5 years of planting, 90.9, 95.3 and 84.0% survival in 1.0, 1.5 and 2.0 m distance, respectively were recorded in outer row. Similarly, 100.0, 88.4 and 88.0% survival in 1.0, 1.5 and 2.0 m distance, respectively were recorded in inner row (Table 43).

Bio-fence model-4 consists of two rows of *A. senegal* (inner and outer) kept at 1.5 m apart wherein plant to plant distance was also 1.5 m. This model was planted along two sides of a well-established *Punica granatum* (pomegranate) orchard. Planting was done in staggered manner in two rows. After 1.5 years of planting, survival of 69.6 and 44.2% were recorded from inner and outer rows, respectively (Table 43).

Table 43: Plant growth and their survival in different bio-fence models at institute research farm (after 1.5 years of planting)

Bio-fence models	Survival (%)	CD (mm)	Height (cm)	Canopy spread (m^2)
Model-1 (Single row)				
Acacia senegal	95.5	11.95	65.7	0.16
Carissa carandas	84.1	4.31	31.7	0.03
Model-2 (Double row)				
Acacia senegal	86.7	8.47	60.3	0.02
Carissa carandas	92.6	3.58	21.0	0.01
Model-3 (Double row)				
Acacia senegal (outer row) - 1.0 m	90.9	11.54	70.5	0.06
Acacia senegal (outer row) - 1.5 m	95.3	15.02	92.8	0.05
Acacia senegal (outer row) - 2.0 m	84.0	11.70	80.3	0.04
Acacia senegal (inner row) - 1.0 m	100.0	16.46	96.6	0.11
Acacia senegal (inner row) - 1.5 m	88.4	15.20	87.5	0.04
Acacia senegal (inner row) - 2.0 m	88.0	14.07	82.9	0.05
Model-4 (Double row)				
Acacia senegal (outer row)	69.6	9.79	64.8	0.13
Acacia senegal (inner row)	44.2	17.13	99.8	0.35

B2. At farmer's fields

During rainy season of 2019, more than 22000 seedlings of *A. senegal* were raised in nursery at ICAR-CAFRI, Jhansi, and provided on payment basis for planting in seven districts (Jhansi, Lalitpur, Jalaun, Hamirpur, Mahoba, Banda and Chitrakut) of Bundelkhand, Uttar Pradesh (Table 44) under the scheme of Doubling Farmers' Income. At each site, 4-5 farmers were identified for developing horticulture/agri-horticulture/agri-horti-silviculture model under the Doubling Farmers' Income project of

Government of Uttar Pradesh in collaboration with ICRISAT, Hyderabad and ICAR-CAFRI, Jhansi. *A. senegal* has been planted on field boundaries, as it acts as bio-fence. The survival (%) of *A. senegal* planted on different farmers' field could not be assessed.

Survival (%) of seedlings planted in various villages/sites during rainy season of 2018 was recorded, which varied from 44.6 (Garhkundar) to 72.7% (Indragarh) in *A. senegal*, from 33.9 (Parasai) to 60.0% (Dhikoli) in *C. carandas*, from 37.7 (Parasai) to 54.0% (Binwara) in *C. limon*, from 35.0 (Garhkundar) to 40.0% (Dhikoli) in *D. strictus*, and 64.0% in *P. guajava* (Table 44).

Observation on survival (%) of *A. senegal* along with *C. limon*, *P. guajava* and *P. granatum*, planted in the field of 14 farmers of village Parasai during 2017, was also recorded which varied from 55.1 to 88.0% in *A. senegal*, from 35.0 to 78.0% in *C. limon*, and from 40.0 to 67.3% in *P. guajava*. Out of 22 plants of *P. granatum* planted in the field of Shri Komal Singh, only 9 plants are surviving (40.9% survival)(Table 45).

Table 44: Survival (%) of gum-yielding and horticultural plants in different villages planted during 2019-20 and 2018-19

Village	*Acacia senegal*		*Carissa carandas*		*Citrus limon*		*Dendrocalamus strictus*		*Psidium guajava*	
	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)
2019-20										
Jhansi	3714	**	-	-	-	-	-	-	-	-
Lalitpur	3714	**	-	-	-	-	-	-	-	-
Jalaun	3714	**	-	-	-	-	-	-	-	-
Hamirpur	2550	**	-	-	-	-	-	-	-	-
Mahoba	2200	**	-	-	-	-	-	-	-	-
Banda	2750	**	-	-	-	-	-	-	-	-
Chitrakut	3000	**	-	-	-	-	-	-	-	-
Total	21642									
2018-19										
Indragarh	300	72.7	-	-	-	-	-	-	-	-
Talbehat)	1000	71.0	-	-	-	-	-	-	-	-
Kotkhera	100	59.0	-	-	5	40.0	50	38.0	-	-
Gadhkundar	350	44.6	30	53.3	-	-	20	35.0	-	-
Binwara	250	47.6	20	45.0	100	54.0	-	-	-	-
Dhikoli	30	53.3	10	60.0	10	40.0	10	40.0	-	-
Parasai	400	62.0	310	33.9	130	37.7	-	-	25	64.0
CAFRI campus	575	61.0	200	56.0	-	-	-		-	-
Total	3005		570		245		80		25	

** Not assessed

Table 45: Survival (%) of gum-yielding and horticultural plant speciesplanted in village Parasai during rainy season of 2017

Farmer's name	Plant species							
	Acacia senegal		*Citrus limon*		*Psidium guajava*		*Punica granatum*	
	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)
Shri Arjun Yadav	400	61.5	--	--	--	--	--	--
Shri Sukhnandan	350	55.1	5	60.0	5	40.0	--	--

Shri Rajveer Yadav	300	74.7	--	--	--	--	--	--
Shri Bisunnath	250	66.8	50	58.0	--	--	--	--
Shri Mahendra	150	88.0	--	--	--	--	--	--
Shri Komal Singh	250	78.8	50	78.0	55	67.3	22	40.9
Shri Bantoo	100	68.0	--	--	--	--	--	--
Shri Prema	100	63.0	--	--	5	60.0	--	--
Shri Jahar Singh	50	62.0	--	--	--	--	--	--
Shri Ashok	150	64.0	5	40.0	--	--	--	--
Shri Vinod	100	71.0	--	--	--	--	--	--
Shri Sushil	--	0.0	5	40.0	--	--	--	--
Shri Shri Mathura Prasad	--	0.0	15	40.0	15	40.0	--	--
Shri Narendra Yadav	--	0.0	20	35.0	20	50.0	--	--

C. Studies on Biomass and Carbon Stock in *Acacia senegal* and *Acacia nilotica*

Studies on estimation of above-ground biomass (AGB; kg/tree) and below-ground biomass (BGB; kg/tree), and carbon (C) stock (tonnes/ha) and C sequestration rate (tonnes/ha/year) of *A. senegal* and *A. nilotica* planted in *rainfed* agri-silviculture model was carried out. This model comprising of *A. senegal* and *A. nilotica* planted in three spacing *viz*., 10 m × 10 m (100 trees/ha), 10 m × 5 m (200 trees/ha) and 5 m × 5 m (400 trees/ha) was established during July, 2013 at ICAR-CAFRI research farm. Annual data on growth *i.e.* plant height (cm) and DBH (cm) are being recorded since its plantation, which were used to calculate the AGB, BGB, C stock and C sequestration rate. The allometric equation ($Y=0.904(DBH)^{1.760}$) developed by ICAR-CAFRI, Jhansi for *A. nilotica* was used to compute AGB; however, for *A. senegal*, no equation was found for our region. Hence, considering the growth habit and characteristics of both the plant species, the same equation ($Y=0.904(DBH)^{1.760}$) was also used for *A. senegal*. With regard to BGB, a factor of 0.26 of the AGB was used to estimate the BGB. Total biomass (TB = AGB+BGB) was used to calculate C stock (tonnes/ha). The C stock was estimated as 47.5% of TB which was further used for calculating C sequestration rate (tonnes/ha/year).

Study recorded maximum AGB, BGB and TB in *A. senegal* and *A. nilotica* planted in 5 m × 5 m, followed by 10 m × 5 m and 10 m × 10 m spacing throughout the study period, barring few exceptions. The TB varied from 1259 to 4475 kg/ha after three years, from 2045 to 7228 kg/ha after four years, 3256 to 10333 kg/ha after five years, 4766 to 14927 kg/ha after six years and 7002 to 20760 kg/ha after seven years of planting of*A. senegal* in various spacing regimes. Similarly, for *A. nilotica*, it varied from 1484 to 8180 kg/ha after three years, 2067 to 14242 kg/ha after four years, 3393 to 14927 kg/ha after five years, 6263 to 20627 kg/ha after six years and 6591 to 24766 kg/ha after seven years of planting in different spacing. Comparatively higher AGB, BGB and TB were recorded in *A. nilotica* when compared with *A. senegal*, irrespective of planting spacing (Table 46). Per cent annual increment in TB of *A. senegal* was recorded in following manner: 75% (4^{th} year), 32% (5^{th} year), 56. (6^{th} year) and 35% (7^{th} year). Similarly, in *A. nilotica*, the per cent increase in TB was 69% (4^{th} year), 10% (5^{th} year), 52% (6^{th} year) and 18% (7^{th} year).

Among spacing regimes, maximum C stock was recorded in 5 m × 5 m, followed by 10 m × 5 m and 10 m × 10 m in both the plant species duringentire study (Table 47). The average estimated C stock in *A. senegal* was 1.13 (3^{rd} year), 1.99 (4^{th} year), 2.63 (5^{th} year), 4.11 (6^{th} year) and 5.56 tonnes/ha (6^{th} year) irrespective of planting spacing. Similarly, the average estimated C stock in *A. nilotica* was 1.98, 3.35, 3.68, 5.60 and 6.58 tonnes/ha during 3^{rd}, 4^{th}, 5^{th}, 6^{th} and 7^{th} years, respectively. Increase in C stock in *A. senegal* and

A. nilotica with increase in their age was recorded. Comparatively higher C stock was recorded in *A. nilotica*than *A. senegal.*

Maximum rate of C sequestration (tonnes/ha/year) was recorded in 5 m × 5 m, followed by 10 m × 5 m and 10 m × 10 m spacing in both the plant species every year, barring few exceptions. The average estimated rate of C sequestration in *A. senegal* was found in respective order as 0.38, 0.50, 0.53, 0.69 and 0.79 tonnes/ha/year during 3rd, 4th, 5th, 6th and 7th years, respectively irrespective of planting spacing. Similarly, the average estimated rate of C sequestration in *A. nilotica* was 0.66, 0.84, 0.74, 0.93 and 0.94 tonnes/ha/year during 3rd, 4th, 5th, 6th and 7th years, respectively (Table 47). Increase in the rate of C sequestration with increase in the age of both plant species was recorded, barring few exceptions. Relatively higher rate of C sequestration rate was noticed in *A. nilotica* than *A. senegal*.

Table 46: Biomass (kg/ha) of *Acacia senegal* and *Acacia nilotica* planted in different spacing (m) geometry in rainfed agri-silviculture model

Parameter	*A. senegal*			Average	*A. nilotica*			Average
	10 ×10	10 × 5	5 × 5		10 × 10	10 × 5	5 × 5	
3YAP*								
AGB#	1000	1131	3552	1894	1178	2234	6492	3301
BGB	260	294	923	492	306	581	1688	858
TB	1259	1425	4475	2387	1484	2814	8180	4159
4YAP								
AGB	1623	2638	5736	3333	1641	3831	11304	5592
BGB	422	686	1491	866	427	996	2939	1454
TB	2045	3324	7228	4199	2067	4827	14242	7046
5YAP								
AGB	2584	2417	8201	4401	2693	3907	11847	6149
BGB	672	628	2132	1144	700	1016	3080	1599
TB	3256	3045	10333	5545	3393	4923	14927	7748
6YAP								
AGB	3783	4997	11847	6875	4971	6723	16371	9355
BGB	983	1299	3080	1788	1292	1748	4256	2432
TB	4766	6296	14927	8663	6263	8470	20627	11787
7YAP								
AGB	5557	5832	16476	9288	5231	8081	19656	10989
BGB	1445	1516	4284	2415	1360	2101	5111	2857
TB	7002	7349	20760	11703	6591	10182	24766	13846

*YAP- Years after planting; #AGB- above ground biomass, BGB- below ground biomass, TB- total biomass

Table 47: Carbon stock (tonnes/ha) and carbon sequestration rate (tonnes/ha/year) in *Acacia senegal* and *Acacia nilotica* growing in rainfed agri-silviculture model

Plant species	Spacing (m)	3 years	4 years	5 years	6 years	7 years
Carbon stock (tonnes/ha)						
Acacia senegal	10×10	0.60	0.97	1.55	2.26	3.33
	10×5	0.68	1.58	1.45	2.99	3.49
	5×5	2.13	3.43	4.91	7.09	9.86
	Mean	1.13	1.99	2.63	4.11	5.56

Acacia nilotica	10×10	0.70	0.98	1.61	2.98	3.13
	10×5	1.34	2.29	2.34	4.02	4.84
	5×5	3.89	6.77	7.09	9.80	11.76
	Mean	1.98	3.35	3.68	5.60	6.58
Carbon sequestration rate (tonnes/ha/year)						
Acacia senegal	10×10	0.20	0.24	0.31	0.38	0.48
	10×5	0.23	0.39	0.29	0.50	0.50
	5×5	0.71	0.86	0.98	1.18	1.41
	Mean	0.38	0.50	0.53	0.69	0.79
Acacia nilotica	10×10	0.23	0.25	0.32	0.50	0.45
	10×5	0.45	0.57	0.47	0.67	0.69
	5×5	1.30	1.69	1.42	1.63	1.68
	Mean	0.66	0.84	0.74	0.93	0.94

D. Economic Analysis of an Agri-Horti-Silviculture Model

Economic analysis of a ten years old agri-horti-silviculture model (field no. 25) was done on the basis of the opportunity costs of different inputs.Cost components for the model was divided into following categories: Establishment cost (A) consisted of cost of establishment of woody perennials or tree component incurred in the beginning of the year of the planting (field preparation, cost of seedlings and their plantation, plant protection, watering etc.); Operational cost (B) included the cost incurred in subsequent years for maintenance of agroforestry model, cultivation of intercrops-seeds and fertilizers, irrigation, harvesting, threshing etc.; Total working capital (C) included the establishment cost (A) and operational cost (B); Interest (@3%) on working capital (C) gave the cost (D); Total variable cost (E) was sum of cost of C and D; Rental value of the land (` 8000-10000/ha) was categorized as cost F; cost G included the Total variable cost (E) and Rental value (F); the cost H was Risk management calculated at 10% of cost G. As measures of economic efficiency, Benefit: Cost (B: C) ratio, Net Present Value (NPV), Payback Period (PBP) and Internal Rate of Return (IRR) were used. B: C ratio was worked out by dividing total returns or cash flow from the system by total cost of working capital including cost of cultivation of intercrops and maintenance of the model on year to year basis. The NPV is merely the algebraic difference between discounted benefits and discounted costs as they occur over time. IRR is the annual earning rate of the project. It is calculated to present the capacity of model to generate regular profit and for comparison with cost of capital. The PBP was worked out by dividing discounted total cost by annual increase in income or mean discounted benefits. For calculating B: C ratio, certain basic assumptions for input costs/output or returns were considered. As far as possible, prevailing unit rates for various inputs and outputs were used.

The total expenditure incurred during 1st year was ₹ 42280/ha which declined during 2nd year (₹ 25863/ha). Comparatively higher input cost during 1st year was due to establishment cost of the model (₹ 10950/ha). Total expenditure included only maintenance cost of the model as well as cost of cultivation of intercrops 2nd year onwards. During subsequent years, increase in the cost of cultivation or working capital, owing to inflation on year to year basis, with increase in the age of the model was noticed. During entire study, the maintenance cost of the model varied from ₹ 1380 to 1980/ha/year and cost of cultivation of intercrops from ₹ 21463 to 59125/ha/year (Table 48). This variation was due to the type of crops grown and variation in cost of their cultivation. The returns from intercrops varied from ₹ 18800 to

101232/ha/year during a period of ten years, and this variation was due to the success or poor yield or failure of crop particularly in summer season. Study also showed that out of ten seasons, summer crops either failed or performed poorly during five seasons (2012-13 to 2016-17) that affected value of total returns from the model. The returns from trees/woody components varied from ₹ 96 to 26052/ha/year. Thus, results signify that total returns from the model depend on the success of intercrops and yield from woody perennial components which varied from ₹ 21532 to 127284/ha/year (Table 49). Table 50 indicated that during 1st year, the annual B: C ratio was 0.74 implying that there was net loss against investment in the model, and this was due to inclusion of establishment cost of the model. In 2nd year also the annual B: C ratio remained less than 1.0, and during 3rd to 5th year, it remained almost static around 1.0; thereafter, it increased considerably and reached up to 2.15 in 10th year.

Table 48: Summary of cost of cultivation (₹) of agri-horti-silviculture model at ICAR-CAFRI, Jhansi for ten years

Year	Tree component		Intercrops		Total capital (₹)	Total working working capital (i.e. C) @ 3%	Interest on cost (₹)	Total variable of land for 0.5 ha (₹)	Rental value	Total	Risk management	Total cost working capital (₹)
	Establishment cost (₹)	Maintenance cost (₹)	Summer	Winter								
	(A)	(A)	(B1)	(B2)	(B) = B1+B2	(C) = A+B	(D)	(E) = C+D	(F)	(G) = E+F	@ 10% of G	
2009-10	10950	--	9120	9480	18600	29550	887	30437	8000	38437	3844	42280
2010-11	--	1660	5320	8080	13400	15060	452	15512	8000	23512	2351	25863
2011-12	--	1628	8520	9744	18264	19892	597	20489	8000	28489	2849	31338
2012-13	--	1740	--	10056	10056	11796	354	12150	8000	20150	2015	22165
2013-14	--	1580	--	8626	8626	10206	306	10512	9000	19512	1951	21463
2014-15	--	1380	5780	22300	28080	29460	884	30344	9000	39344	3934	43278
2015-16	--	1780	--	26470	26470	28250	848	29098	9000	38098	3810	41907
2016-17	--	1480	--	33256	33256	34736	1042	35778	9000	44778	4478	49256
2017-18	--	1680	10120	17865	27985	29665	890	30555	9000	39555	3955	43510
2018-19	--	1980	13798	26698	40496	42476	1274	43750	10000	53750	5375	59125

Table 49: Summary of returns (₹) from agri-horti-silviculture model at ICAR-CAFRI, Jhansi for ten years

Year	Returns (₹) from intercrops			Returns (₹) from trees			Total returns (₹)
	Summer	Winter	Total	Tree	Fruit	Total	
2009-10	16600	14748	31348	--	--	--	31348
2010-11	14742	6940	21682	--	--	--	21682
2011-12	15360	18300	33660	96	--	96	33756
2012-13	--	19800	19800	668	1440	2108	21908
2013-14	--	18800	18800	212	2520	2732	21532
2014-15	--	47630	47630	1860	2040	3900	51530
2015-16	--	45660	45660	1588	5940	7528	53188
2016-17	--	67040	67040	4990	6640	11630	78670
2017-18	17960	24240	42200	8318	11300	19618	61818
2018-19	16620	84612	101232	13252	12800	26052	127284

Table 50: Summary of benefit-cost analysis of agri-horti-silviculture model at ICAR-CAFRI, Jhansi for ten years

Year	Intercrop grown		Total cost of cultivation (₹)	Total returns (₹)	B:C ratio
	Summer	Winter			
2009-10	*P. mungo*	*B. campestris*	42280*	31348	0.74
2010-11	*P. mungo*	*L. culinaris*	25863@	21682	0.84
2011-12	*P. mungo*	*B. campestris*	31338	33756	1.08
2012-13	Poor/ Failed	*B. campestris*	22165$	21908	0.99
2013-14	Poor/ Failed	*B. campestris*	21463$	21532	1.00
2014-15	Poor/ Failed	*T. aestivum*	43278#	51530	1.19
2015-16	Poor/ Failed	*T. aestivum*	41907$	53188	1.26
2016-17	Poor/ Failed	*T. aestivum*	49256$	78670	1.60
2017-18	*V. radiata*	*B. campestris*	43510	61818	1.42
2018-19	*P. mungo*	*T. aestivum*	59125	127284	2.15

*Includes cost of establishment of agroforestry model during first year; @Includes cost of maintenance of agroforestry model during subsequent years; $Summer crop was not sown; #Summer crop was sown but failed and benefits accrued as green manuring not accounted

Summary of discounted cost, returns and B: C ratio, NPV, IRR and PBP has been given in Table 51. To neutralize the impact of inflation, the discounted rate is assumed as 12%. The total discounted cost for model of 10 years was found as ₹ 202442/ha and discounted total returns was found as ₹ 240656/ha. The discounted B: C ratio was found as 1.19 for the model. The NPV of the model (discounted total returns-discounted total cost), reflecting current worth of the model, is found as ₹ 38214/ha. The IRR is the rate of return or profit from the model. The rate of return of the model is to be compared with cost of capital (rate of interest). In this model, the IRR is found as 18.29%, and this is sufficiently above the rate of interest of 12%. On the basis of annual returns from the model, the PBP is found as 8.41 years. It implies that in this period, the total cost of the model spent in 10 years is recovered and after that model has generated net profits only.

Results also showed that component wise returns from the model was not always static, it faced ups and down due to poor and/or failed summer crop, while returns from tree components increased continuously from 3rd year onwards. In the study, maximum loss due to failure of summer crops was equated with the maximum returns from successful summer crop which was ₹ 17960/ha obtained during 9th year (2017-18). Winter season crop never failed; however, returns from winter crop varied and depended on the type of crops cultivated and its performance. Despite failure of summer crop during 4th to 8th years, the annual B: C ratio either maintained around 1.0 or was more than 1.0 implying that the failed crop losses were compensated by usufructs from woody components which started giving return from 3rd year onwards and from horticulture component which started giving return from 4th years onward (Fig. 25). Results also suggested that trees/fruit components reduced payback period of the model exhibiting its potential to act as a sink for climate related risks in agricultural production system. *A. senegal* started yielding gum naturally 6th years onward. Increase in its production was noticed with the age of the model. General decline in per cent share of returns from intercropping in total returns from the model was noticed. After ten years, it wasrecorded up to 20% which was compensated fully by increasing share of trees/woody components of the model (Fig. 26). After ten years of establishment of the model, the annual B: C ratio of 2.15 indicates that a farmer may earn ₹ 2.15 against per rupee invested in agri-horti-silviculture model on his farm, and this rate of returns is likely to increase further with increase in the returns from tree/woody components with the age of the model.

Table 51: Discounted cost, returns and B: C ratio at 12% discount rate for agri-horti-silviculture model

Year	Discounted total cost (₹/ha)	Discounted total returns (₹/ha)	Net Present Value (₹/ha)
2009-10	37750	27989	-9761
2010-11	20618	17285	-3333
2011-12	22306	24027	1721
2012-13	14086	13923	-163
2013-14	12179	12218	39
2014-15	21926	26107	4181
2015-16	18957	24060	5103
2016-17	19894	31773	11880
2017-18	15690	22292	6602
2018-19	19037	40982	21945
Total	202442	240656	38214
Average	20244	24066	
B: C ratio at discounted rate of 12% after ten years			1.19
Internal Rate of Return after ten years (%)			18.29
Payback Period (years)			8.41

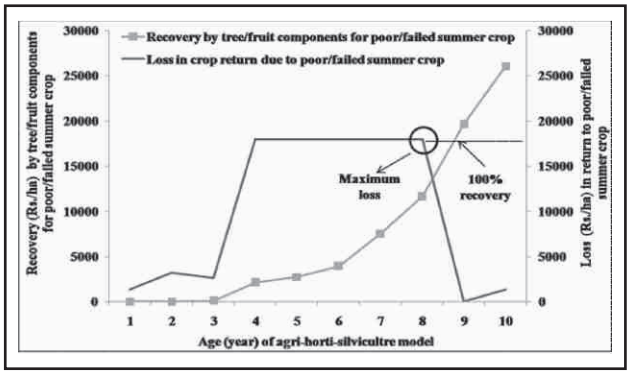


Fig. 25: Recovery (₹) by trees/fruit component for losses due to poor/failed summer crop in agri-horti-silviculture model

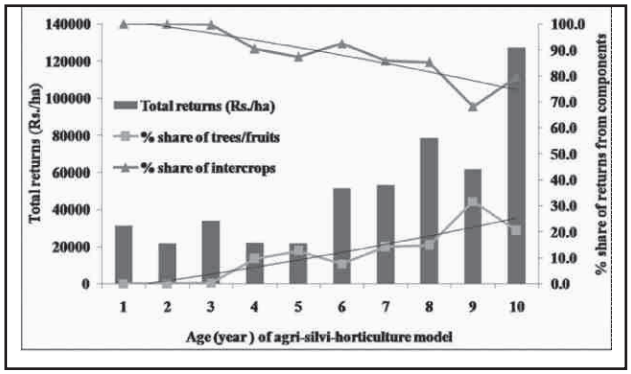


Fig. 26: Share of different components of agri-horti-silviculture model in total returns (₹)

E. Studies on Soil Moisture Dynamics

Studies on soil moisture content (%) of various gum-yielding tree based agroforestry models was initiated during September, 2019 with the aim to assess relation between natural exudation of gums from *A. senegal* and *A. nilotica* with soil moisture content (%). For the purpose, soil samples were collected from two different depth (0-15 and 15-30 cm) of *A. senegal* and *A. nilotica* (within 0.5 m distance from tree trunk) growing in agri-horti-silviculture model (filed no. 25), horti-silviculture model (field no. 20), *ranifed* agri-silviculture model (field no. 40 & 41) and gum gardens (new and old) at 15 days interval. Moisture content (%) was determined by gravimetric method. The data recorded so far on moisture content are being presented in Table 52 and 53. Higher moisture content was recorded in soil samples collected from sub-surface (15-30 cm). Generally, soil moisture declined in both the soil layers with passage of time from the month of September to March in all fields barring period of winter rain and irrigation applied to wheat crop in agri-horti-silviculture model in field no. 25.

Table 52: Moisture content (%) in soils collected from agri-horti-silviculture model, horti-silviculture model and gum gardens

Plant species	Depth (cm)	30 Sept, 2019	06 Nov, 2019	26 Nov, 2019	05 Dec, 2019	23 Dec, 2019	04 Jan, 2020	20 Jan, 2020	06 Feb, 2020	20 Feb, 2020	07 Mar, 2020	20 Mar, 2020
Agri-horti-silviculture (field no.25)												
A. senegal	0-15	16.37	6.76	10.93	6.90	15.15	13.03	15.36	14.56	14.17	8.23	7.86
	15-30	14.90	8.12	11.98	5.39	13.82	15.38	17.00	11.27	15.03	7.25	17.61
C. limon	0-15	15.40	7.22	7.67	9.08	18.81	19.80	15.36	11.75	13.15	12.36	8.98
	15-30	14.29	9.91	9.22	7.46	16.07	18.40	14.60	11.88	18.50	7.22	8.46
A. marmelos	0-15	16.62	4.36	10.35	5.48	19.70	13.29	18.53	14.49	13.77	10.50	8.59
	15-30	20.02	5.93	9.78	10.54	14.96	14.52	16.28	11.31	14.97	5.74	7.30
C. carandas	0-15	18.87	10.00	10.07	9.24	16.05	14.96	18.19	15.54	12.38	8.93	8.92
	15-30	20.52	12.04	16.29	16.07	15.77	17.78	17.28	12.84	14.77	8.51	8.26
Open	0-15	13.70	11.76	13.96	10.34	20.72	17.84	17.96	12.67	11.49	8.58	10.33
	15-30	18.29	14.21	15.15	17.28	19.24	15.63	15.91	11.52	14.76	9.29	9.54
Horti-silviculture (field no. 20)												
Plant species	**Depth (cm)**	**24 Oct, 2019**	**06 Nov, 2019**	**26 Nov, 2019**	**05 Dec, 2019**	**23 Dec, 2019**	**04 Jan, 2020**	**20 Jan, 2020**	**03 Feb, 2020**	**19 Feb, 2020**	**07 Mar, 2020**	**20 Mar, 2020**
A. senegal	0-15	18.03	6.80	5.34	5.36	5.18	7.32	13.97	5.73	6.77	5.36	2.43
	15-30	16.01	6.07	5.76	6.77	7.43	7.06	15.01	8.88	8.80	11.27	6.26
A. nilotica	0-15	18.73	18.44	16.90	7.95	6.67	7.22	11.08	8.67	7.75	7.87	4.58
	15-30	11.14	7.01	13.29	7.07	6.65	7.14	14.00	12.78	6.70	12.59	5.73
Open	0-15	16.47	15.27	12.64	10.01	9.40	12.18	14.32	9.60	9.33	6.06	3.45
	15-30	15.93	17.92	11.45	13.68	12.95	12.15	13.49	12.63	12.68	8.80	5.56
New gum garden												
Plant species	**Depth (cm)**	**04 Oct, 2019**	**06 Nov, 2019**	**26 Nov, 2019**	**05 Dec, 2019**	**23 Dec, 2019**	**04 Jan, 2020**	**20 Jan, 2020**	**03 Feb, 2020**	**19 Feb, 2020**	**07 Mar, 2020**	**20 Mar, 2020**
A. senegal	0-15	15.69	4.16	3.71	4.56	3.91	9.89	12.32	4.61	2.03	4.17	2.23
	15-30	13.44	5.12	5.17	7.03	4.16	5.44	11.46	8.41	5.40	3.93	5.41
Open	0-15	14.78	3.68	4.61	4.19	3.74	7.44	12.36	3.96	2.08	4.58	1.80
	15-30	13.47	4.61	5.15	6.47	5.38	5.87	11.92	6.45	5.07	3.18	4.29
Old gum garden												
Plant species	**Depth (cm)**	**04 Oct, 2019**	**06 Nov, 2019**	**26 Nov, 2019**	**05 Dec, 2019**	**23 Dec, 2019**	**04 Jan, 2020**	**20 Jan, 2020**	**03 Feb, 2020**	**19 Feb, 2020**	**07 Mar, 2020**	**20 Mar, 2020**
A. senegal	0-15	20.30	7.80	5.89	4.70	6.00	13.54	17.81	6.67	3.40	6.40	2.07
	15-30	16.32	9.76	4.83	6.89	7.02	6.72	15.18	9.49	3.76	4.53	4.90
Open	0-15	13.67	4.60	6.11	5.30	5.49	9.56	19.17	5.54	3.06	5.00	1.76
	15-30	12.79	4.44	6.52	9.02	10.50	6.72	14.79	9.67	5.33	4.14	4.30

Table 53: Moisture content (%) in soils collected from *rainfed* agri-silviculture system

Plant species	Distance (m)	Depth (cm)	04 Oct, 2019	06 Nov, 2019	26 Nov, 2019	05 Dec, 2019	23 Dec, 2019	04 Jan, 2020	16 Jan, 2020	03 Feb, 2020	19 Feb, 2020	07 Mar, 2020	20 Mar, 2020
A. senegal	5×5	0-15	18.00	9.03	6.25	7.04	7.28	10.34	12.57	7.80	4.05	3.79	2.91
	5×5	15-30	20.30	8.81	6.02	10.26	7.25	10.85	13.90	8.26	6.60	5.25	4.68
	10×5	0-15	13.94	5.17	5.05	5.05	5.46	6.74	14.56	10.04	3.19	3.38	1.67
	10×5	15-30	13.27	4.96	5.77	5.65	5.94	8.35	14.36	9.07	8.13	4.79	3.73
	10×10	0-15	16.31	4.99	4.97	6.36	9.23	4.96	13.00	5.96	4.13	3.95	1.55
	10×10	15-30	17.29	7.99	7.84	7.83	13.86	5.99	14.02	7.28	6.55	4.09	3.63
A. nilotica	5×5	0-15	15.79	9.19	6.06	5.53	6.95	10.75	11.69	7.81	4.74	4.29	1.31
	5×5	15-30	16.92	9.63	5.68	5.99	7.22	11.13	14.10	8.47	7.54	5.26	4.97
	10×5	0-15	15.93	6.60	4.56	4.42	4.85	5.84	13.73	6.21	3.47	3.97	2.50
	10×5	15-30	16.26	6.89	6.32	7.49	7.19	6.24	13.88	9.52	9.08	4.77	3.84
	10×10	0-15	15.57	7.05	7.11	5.24	8.13	7.05	12.86	6.67	5.52	7.63	1.59
	10×10	15-30	16.87	7.48	10.23	7.20	11.43	7.48	14.66	6.41	8.21	6.21	3.33
Open	0-15		14.88	8.74	5.45	4.40	4.93	6.44	12.95	5.77	4.09	4.69	1.74
	15-30		16.20	10.28	7.16	9.38	7.36	6.06	13.61	9.29	8.85	6.45	3.51

NICRA National Innovations on Climate Resilient Agriculture

NRMACAFRISOL201100300087

I- Assessment of carbon sequestration potential of agroforestry systems existing on farmer's field in different agro-climatic regions

(Badre Alam, Ram Newaj, Rajendra Prasad, AK Handa, RH Rizvi and SB Chavan)

The baseline survey information of existing tree species on farmers' field in Kamrup district of Assam was provided by the All India Co-ordinated Research Centre of Agroforestry under Assam Agricultural University, Jorhat to assess the carbon sequestration potential of agroforestry systems. The general description of study area, major crops and their productivity and dominant tree species in total tree population is given in Table 54. The most common tree species on farmers' field are *Areaca catechu, Hevea brasiliensis, Tectona grandis, Shorea robusta, Gmelina arborea, Babusa tulda, Syzygium cumini* and *Cocos nucifera.* Among these tree species, percentage contribution of *Areca catechu* and *Hevea brasiliensis* is 39.89 and 32.21%, respectively. The average tree density under agroforestry existing on farmer's field in Kamrup district of Assam was 130.58 trees /ha. In this districts, density of medium growing tree species (117.5 tree/ha) are more than fast growing (6.90 tree/ha) and slow growing trees (6.11 tree/ha). However, the medium growing tree species are highly dominated and consists of their contribution above 90.4 % (Fig. 27).

Assessment of carbon sequestration potential (CSP) of agroforestry system existing on farmer's field was done through CO2FIX simulation model. Tree biomass, total biomass (tree + crop), biomass carbon, soil carbon, net carbon sequestered over simulated period of 30-years and carbon sequestration potential (CSP) of surveyed district has been given in Table 55, which clearly showed that tree density and environmental influence play an important role in biomass production as well as carbon sequestration. The baseline tree biomass and total (tree+crop) biomass was 17.12 Mg DM /ha and 22.92 Mg DM /ha, respectively. The quantified soil organic carbon in the baseline was 25.47 Mg C /ha and it is likely to be expected to increase up to 42.48 Mg C /ha. The baseline total carbon (biomass+soil) in farmer's field was 48.39 Mg C /ha and will increase up to 181.29 Mg C /ha over the period of 30 years. However, the estimated annual carbon sequestration potential of agroforestry system in Kamrup districts of Assam was 4.43 Mg C /ha/ years. The highest carbon sequestration rate was due to the tree species planted, age of trees, tree per hectare, planting geometry, trees composition, crop productivity, geographic location, soil health, local climatic factors and management regimes etc.A representative picture of bamboo based agroforestry in Kamrup district is given (Plate 18) and also *Areca catechu* and *Tectona grandis* plantation (Plate 19).

Table 54: General description of study area

District	Longitude & Latitude, soil type	Major crops and productivity	Dominant tree species (contribution in %)
Kamrup	25° 44' N , 90° 56' E Sandy loam to clay loam	*Oryza sativa* (3.05), *Triticum aestivum* (5.61), *Brassica* spp (1.88) and Pulses (2.95)	*Areca catechu* (39.83), *Hevea brasiliensis* (32.21), *Tectona grandis* (5.74), *Shorea robusta* (3.24), *Gmelina arborea* (2.62), *Bambusa tulda* (1.74), *Syzygium cumini* (1.03), *Cocos nucifera* (1.01)

Table 55: Biomass, carbon and carbon sequestration potential of agroforestry system existing on farmer's field in Kamrup district of Assam

Parameters			Kamrup (130.58 trees/ha)
Tree Biomass (above and below ground) in Mg DM/ha	Baseline	Biomass	17.12
	Simulated		132.34
Total biomass (tree + crop) in Mg DM / ha	Baseline		22.92
	Simulated		138.81
Soil carbon (Mg C / ha)	Baseline	Carbon	25.47
	Simulated		42.48
Biomass carbon (Mg C / ha)	Baseline		11.01
	Simulated		63.53
Total carbon (biomass + soil) (Mg C / ha)	Baseline		48.39
	Simulated		181.29
Net carbon sequestered in agroforestry systems over the simulated period of thirty years (Mg C / ha)		Carbon sequestered	132.9
Estimated annual carbon sequestration potential of agroforestry system (Mg C / ha/ yr)			4.43

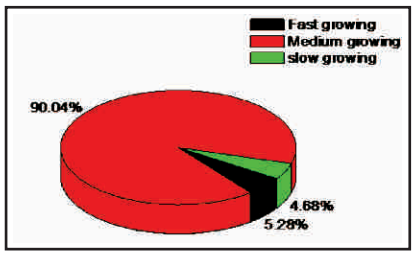


Fig. 27: Relative percentage of fast, medium and slow growing trees in Kamrup districts of Assam

Plate 18:*Bambusa tulda* based agroforestry systems in Kamrup district of Assam

Plate 19: *Areca catechu* and *Tectona grandis* at Farmers' fields in Assam

Biomass prediction models of *Tectona grandis*

The field sampling of teak trees through destructive sampling was also carried out at Raisen districts of Madhya Pradesh to develop biomass estimation models for carbon sequestration studies. A total 34 matured trees of 30-40 years old were selectively harvested and quantified by using standard procedure of biomass estimation. The growth parameters such as diameter at breast height, tree height, fresh weight of teak logs were recorded in field conditions and also small bole samples were taken to quantify dry weight of teak trees. The DBH values of the harvested trees ranged from 14.94 to 38.42 cm and tree height of 11.2 to 19.00 m. The DBH was plotted against dry bole weight of teak trees to testify the regression relationship (Fig. 28). The diameter at breast height was to be best independent predictor over tree height. The best modeled regression equations is power equation ie. Biomass (kg tree-1)=0.3134 × $(DBH)^{2.034}$ with R^2 of 0.94. Fig. 28 indicates the best-fit line of regression of proposed equation. Although the mean absolute error (MAE) for the best-fit model comes out to be 13.83 indicating that an error of only 13.83 Kg may occur in prediction of total tree biomass of teak.

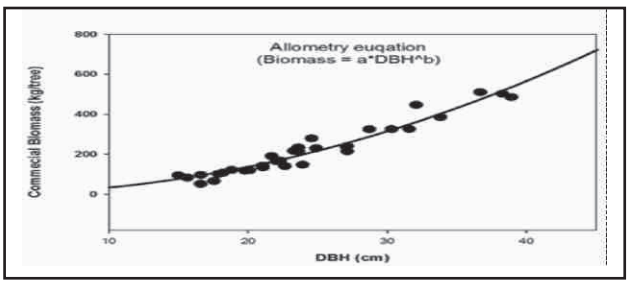


Fig. 28:DBH was plotted against dry bole weight of teak trees to testify the regression relationship

II. Mapping of Agroforestry Area through GIS & Remote Sensing

From agro-climatic zone-2 *i.e.* East Himalayan Region, 15 districts have been selected. They are: Kochbihar, Lunglie, Lohit, East Siang, Churachandpur, MON, Kohima, Dhalai, E. Khasi Hills, Bongaigaon, Jorhat, Dibrugarh, Nagaon, West Sikkim and Nalbari (Fig. 29a). These districts have total geographical area of 5.652 million ha.

Agro-climatic Zone-wise estimated area under agroforestry

For mapping of agroforestry area in selected districts of agro-climatic zone-2, multispectral remote sensing data has been procured from NRSC, Hyderabad. High resolution LISS-IV data has been processed and analyzed using ERDAS Imagine software. For mapping agroforestry, object-based classification method of Imagine Objective tool was applied already developed methodology was adopted. Agroforestry are accounted for more than 10 percent in Kochbihar district of West Bengal, Bongaigaon, Nagaon and Dibrugarh districts of Assam with highest in Kochbihar (18.14%). About six districts have less than one percent area under agroforestry (Table 56). Agroforestry area in selected districts is depicted in Fig. 29b.

Table 56: Estimated agroforestry area in selected districts of agro-climatic zone-2

S.No.	State	District	Geog. Area (ha)	Agroforestry Area (ha)	Area in %
1	West Bengal	Kochbihar	338091.43	61327.33	18.14
2	Assam	Bongaigaon	110921.78	17782.26	16.03
3		Jorhat	283543.89	19668.21	6.94
4		Dibrugarh	354327.53	43322	12.23
5		Nagaon	403105.386	41199.385	10.22
6		Nalbari	107415.08	2176.89	2.03
7	Mizoram	Lunglie	467319.25	811.88	0.17
8	Arunachal Pradesh	Lohit	1103742.47	7260.709	0.66
9		East Siang	642794.00	6090.51	0.95
10	Manipur	Churachandpur	475746.84	4545.79	0.96
11	Nagaland	MON	193199.43	1200.01	0.62
12		Kohima	403484.64	5111.238	1.27
13	Tripura	Dhalai	232608.68	4929.48	2.12
14	Meghalaya	East Khasi Hills	536011.66	1781.44	0.33
	Total/ Average		5652312.08	217207.13	3.84

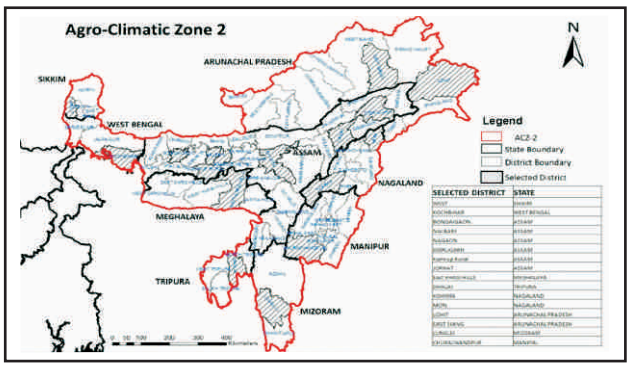


Fig. 29a: Location map of agro-climatic zone-2 and the selected districts

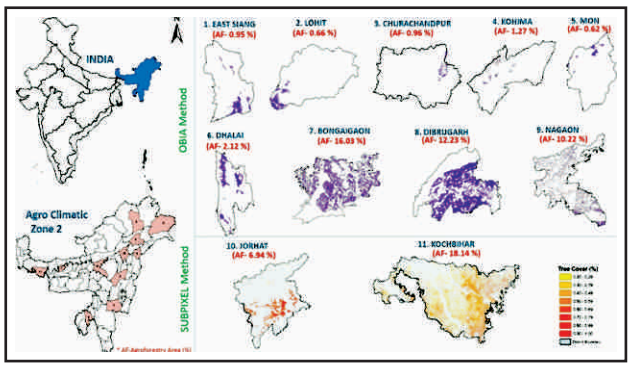


Fig. 29b: Maps of agroforestry area in selected districts of agro-climatic zone-2

III: Studies on thermotolerance of multipurpose tree species of agroforestry importance

Comparative studies of thermotolerance in respect to ambient and elevated temperature on *Albizia procera* (safed siras) and *Azadirachta indica* (neem) have been comprehensively studied. Experiments were continued with the seedlings in polybags under elevated temperature inside a temperature gradient tunnel (TGT) and under ambient condition outside the TGT. Clear trend of responses of the tree seedlings in response to elevated temperature and in ambient conditions were noted. Impact of elevated temperature have been critically studied in terms of the thermotolerance indices namely canopy temperature depression (CTD) and leaf chlorophyll content index (CCI). The efficacy of the leaves for coping with the elevated temperature were reflected in differential responses in leaf physiological functions. Thus, differential responses in CTD were noted. Remarkable effects of elevated temperature on the leaf physiological status have been observed coping with its physiological functions. There were temporal and seasonal changes in canopy temperature depression (CTD) in both the tree species under ambient and elevated temperature (Figs.30,31). Similarly, differential responses in CCI in the seedlings were also noted (Figs. 32,33).

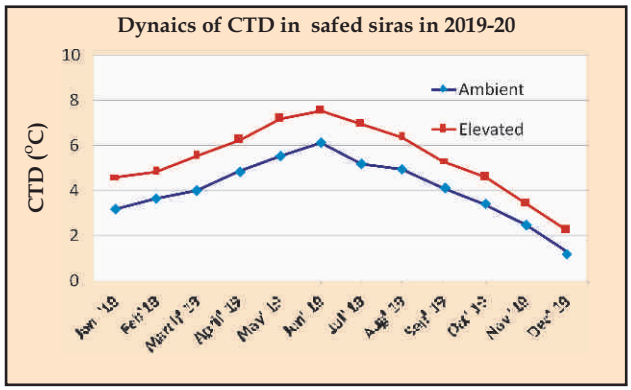


Fig. 30: Dynamics of canopy temperature depression (CTD) of safed siras (*Albizia procera*) under ambient and elevated temperature.

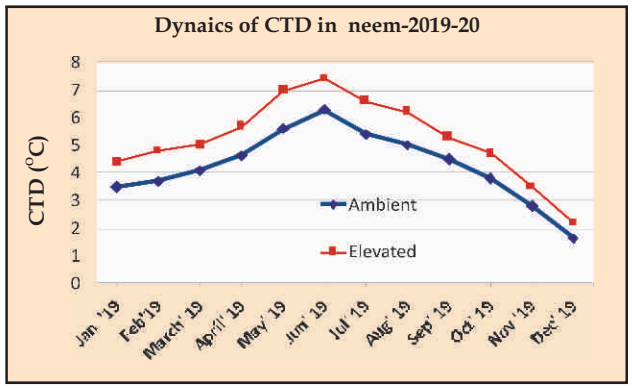


Fig. 31: Dynamics of canopy temperature depression (CTD) of neem (*Azadirachta indica*) under ambient and elevated temperature

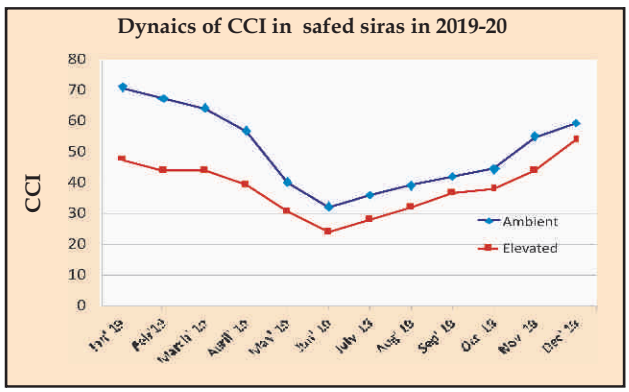


Fig. 32: Dynamics of temporal changes in leaf chlorophyll content index (CCI) of safed siras (*Albizia procera*) under ambient and elevated temperature

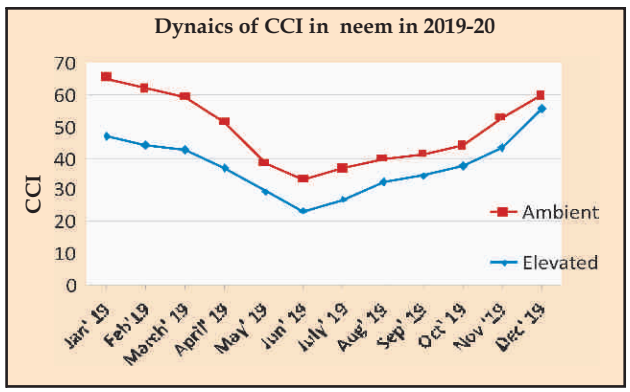


Fig. 33: Dynamics of temporal changes in leaf chlorophyll content index (CCI) of neem (*Azadirachta indica*) under ambient and elevated temperature

ICAR- ICRAF Work Plan

NRMACAFRISOL 201800100112

Mapping and Estimation of Area under Poplar based Agroforestry Systems in Indo- Gangetic Plains of India

(R H Rizvi, A K Handa and K B Sridhar)

In Indo-Gangetic plains of Northern India, Poplar species based agroforestry systems are prevalent in Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Bihar. Mapping and estimation of area under Poplar species is essential for planners to know wood production from this species to meet domestic requirement. Keeping this in view the proposed study has been taken with the following objectives:

Objectives:

- To map and estimate area under poplar plantations on farmland using GIS and remote sensing techniques.
- To assess the biomass/ wood production for existing poplar plantations in Indo-Gangetic region.

Methodology Adopted for Mapping Poplar

1. District-level Poplar Mapping

For mapping of poplar at district level, high resolution LISS-4 data (spatial resolution- 5.8m) has been used. Preprocessing of this data includes layer stacking, mosaicking and clipping of district area with the help of boundary shape file. From district area, forest cover was then masked and remaining area was analyzed in ERDAS Imagine software. For identification of Poplar species, object-oriented classification technique was applied using IMAGINE Objective tool. Object based image analysis (OBIA) segments the pixels into different objects and groups them according to objects. This method utilizes the NDVI image and computes single feature probability (SFP). OBIA method was found better than pixel based classification methods.

2. State-level Poplar Mapping

In case of state, Sentinal-2 data (spatial resolution- 10m) has been used. This data is available in 12 different spectral bands. Top-of-atmospheric (ToA) correction was applied on this data to get the reflectance values for each pixel. Then the images are mosaicked, clipped from state boundary and false colour composite (FCC) was generated. Forest cover area has been masked with the help of FCC and remaining area has been analyzed. Reflectance values for Poplar species were determined with the help of GPS points collected farmers' fields. By applying the range of reflectance values in knowledge classifier, Poplar area has been identified. The resultant images were subjected to correction for removing undesired area along roads, canals and within urban areas. Finally the accuracy was assessed and poplar area statistics calculated for the state.

Poplar Mapping in Punjab

1. Field survey was conducted in Faridkot, Moga, and Bathinda districts of Punjab during Nov. 11-16, 2019. GPS points and tracks on Poplar plantations were recorded, which were used for identification and mapping of Poplar species on farmlands. Very few plantations of Poplar species were found in these districts, some of them were deserted ones. Farmers prefer to grow Eucalyptus and *Melia azadirech* on their fields as boundary and block plantations.
2. Multispectral remote sensing images (LISS-IV) for the year 2019 were procured from NRSC, Hyderabad (Table 57). These images have been layer stacked, mosaicked and analyzed using ERDAS Imagine 2015. Agroforestry area has been mapped and estimated in these districts by applying object oriented classification techniques. From the agroforestry area, Poplar area was identified and mapped with the help of field check points taken through GPS and then accuracy was assessed pre-processed and analyzed for mapping of agroforestry as well as Poplar species Punjab districts.
3. Estimated agroforestry area was found highest in Ferozpur district followed by Hoshiarpur and Moga districts. Agroforestry area in Ferozpur, Hoshiarpur and Moga districts of Punjab come out to be 22068.81 ha

(4.17%), and 19600.38 ha (5.91%), 16000.51 ha (7.11%) respectively. Agroforestry area in Kapurthala, Jalandhar and Tarn Taran districts was estimated to be 5942.25 ha (3.62%), 7698.36 ha (2.90%) and 13456.37 (5.52%), respectively.

4. Estimated Poplar area in terms of hectare was highest in Hoshiarpur district (10573.13 ha), followed by Rupnagar district (5495.20 ha). Poplar based agroforestry systems accounted for more than 50 percent of total agroforestry area in Rupnagar and Hoshiarpur districts (Table 57). Area under Poplar species in Ludhiana, Tarn Taran and Kapurthala, districts has been estimated to be 3698.67 ha (31.6%), 2162.49 ha (and 1814.23 ha, respectively in these districts. Maps of Poplar area of some districts are shown in Figs. 34 to 37.

Agroforestry and Poplar area in 15 districts of Punjab come out to be 176669.95 ha and 31771.62 ha, respectively. Poplar area accounted for about 18 percent of the agroforestry area in these districts. Poplar mapping at state level was also done with Sentinel-2A data using the methodology described above. Poplar species in Punjab state occupied an area of about 0.276 million ha (5.63%) with a reasonably good accuracy of 81 percent.

Table 57: Estimated agroforestry and Poplar area in selected districts of Punjab

S. No.	Name of district	Agroforestry area (ha)	Poplar area (ha)	Poplar area as %age of agroforestry
1.	Rupnagar	9567.30	5495.20	57.4
2.	Hoshiarpur	19600.38	10573.13	53.9
3.	Ludiana	11691.85	3698.67	31.6
4.	Nawashahr	5501.00	534.00	9.7
5.	Kapurthala	5942.25	1814.23	30.5
6.	Jalandhar	7698.36	1694.56	22.0
7.	Tarn Taran	13456.37	2162.49	16.1
8.	Pathankot	13639.90	1297.30	9.5
9.	Gurdaspur	8923.44	1284.45	14.4
10.	Ferozpur	22068.81	1253.61	5.7
11.	Moga	16000.51	558.00	3.5
12.	Faridkot	6731.81	261.38	3.9
13.	Bathinda	10793.34	331.18	3.1
14.	Muktsar	10326.20	248.21	2.4
15.	Amritsar	14722.43	565.21	3.8
Total	176663.95	31771.62	17.98	

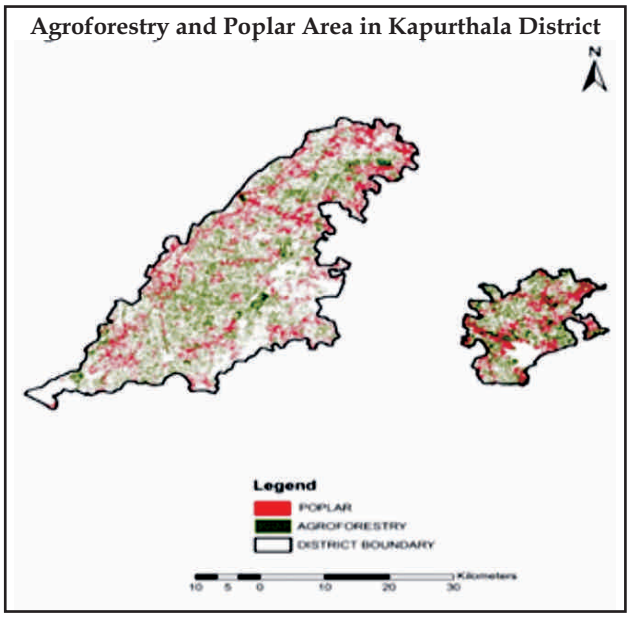


Fig. 34: Poplar area in Kapurthala district of Punjab

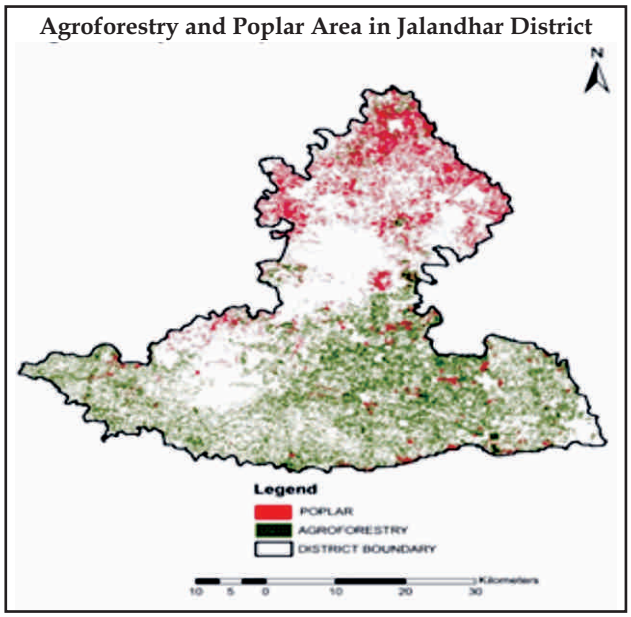


Fig. 35: Poplar area in Jalandhar district of Punjab

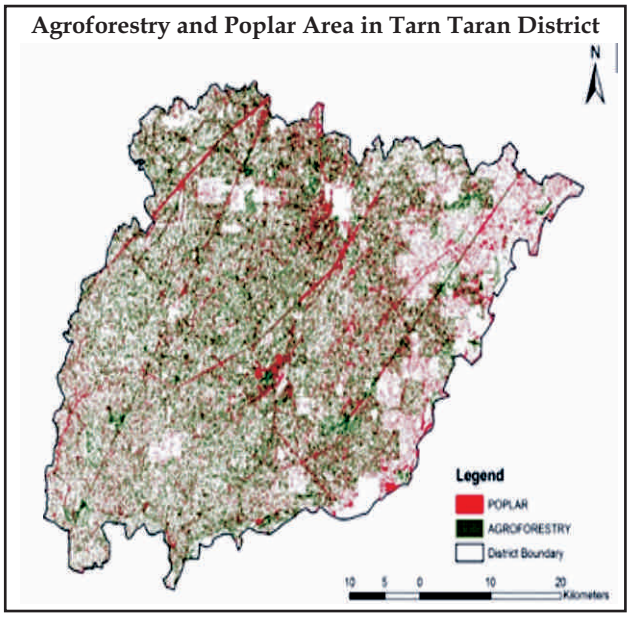


Fig. 36: Poplar area in Tarn Taran district of Punjab

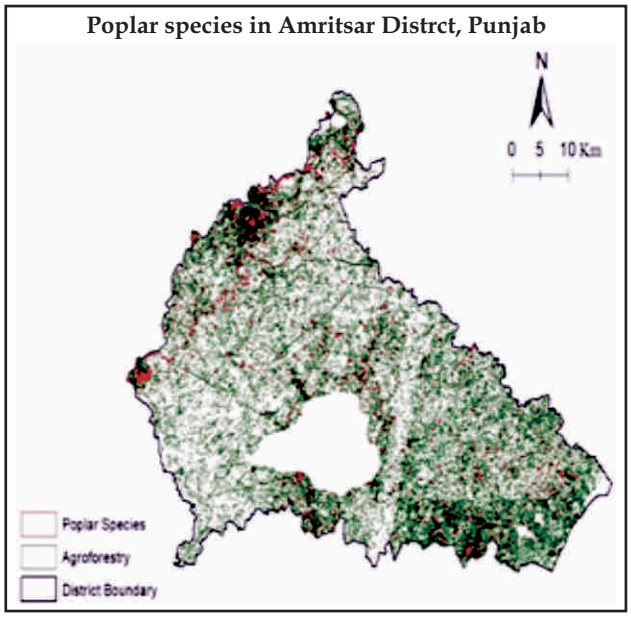


Fig. 37: Poplar area in Amritsar district of Punjab

ICRISAT, Hyderabad

NRMACAFRISOL 201800200114

Transforming rural livelihood through agroforestry based natural resource management in drought prone Bundelkhand region, UP (Sub Project of KISAN MITrA project for Doubling Farmers' Income in Bundelkhand region of Uttar Pradesh)

(Ramesh Singh, Inder Dev, R K Tewari, Naresh Kumar, Asha Ram, Dhiraj Kumar and Lal Chand)

Project sites: The project activities are being implemented in 20 villages of seven district of Bundelkhand U.P. List and location of villages selected under DFI project is depicted in Table 58 and Fig. 38.

Table 58:Location of villages selected under DFI project

Pilot villages identified in seven districts of Bundelkhand and the prevalent major cropping systems in *kharif* and rabi seasons.			
District	**Block**	**Villages**	**Cropping pattern**
Lalitpur	Talbehat	Pura-Khurdh, Birdha, Jhawar	Blackgram, groundnut, mung bean, (*kharif* season-K); peas, wheat, mustard (rabi season-R)
Jhansi	Babina	Imiliya, Rajapur, Amarpur	Groundnut, mungbean, blackgram, sesame (K); wheat, chickpea, mustard (R)
Jalaun	Mahiva	Noorpur, Naserpur, Hydalpur	Peas, Mentha, sesame, vegetables (K); wheat, chickpea (R)
Hamirpur	Sumerpur	Saukhar, Nazarpur, Karimati	Sesame, mung bean, Blackgram, sorghum, millet (K); mustard, wheat, chickpea (R)
Mahoba	Kabarai	Chandpura, Nathupura, Baniyatala	Peas, blackgram, sesame, pigeonpea, mung bean (K); wheat, chickpea (R)
Banda	Thindwari	Benda, Amlikaur, Jauharpur	Pigeonpea, sorghum, sesame, mung bean (K); chickpea, lentil, peas, wheat (R)
Chitrakoot	Karwi	Rowli-Kalyanpur, Rasim	Mung bean, pigeonpea, sesame (K); wheat, peas, chickpea, lentil (R)

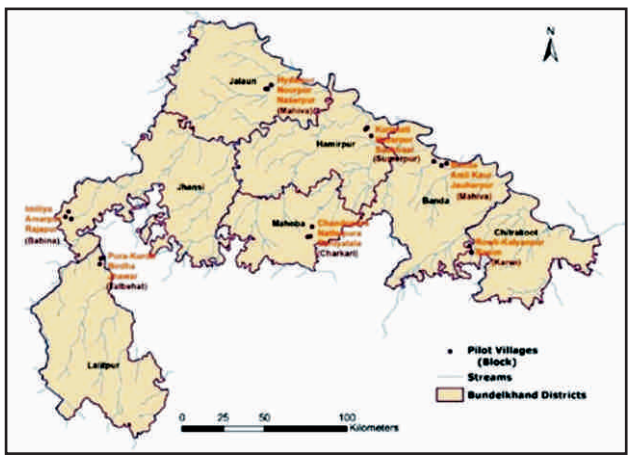


Fig. 38: The location of pilot villages in seven districts of Bundelkhand region.

Major issues identified in the pilot villages

- Water scarcity; mid-season droughts in *kharif* and dried up wells in *rabi*/summer
- *Kharif* season fallow (social issues like *Annapratha*)
- Poor land and water use efficiency
- Low organic carbon and land degradation
- Use of local landraces with low productivity
- Poor mechanization
- Poor livestock productivity (high population but poor yield)
- Widespread fodder scarcity (main reason for Annapratha)
- Poor awareness of improved management practices.

Soil health mapping and awareness building

A stratified soil sampling method (~25-30 ha/sample) was used to collect 1219 soil samples (with geo-reference)(Plate 20) from the pilot

villages. The samples were analyzed at the ICRISAT state-of-the-art laboratory. Table 59Ashows the average available nutrient status in the soil and their range. Results showed that farmers' field are degraded in terms of soil Organic Carbon (OC) and other nutrients. Low OC in fields ranged from 29% in Jhansi to as high as 94% in Jalaun (Table 59B). Low OC levels also indicate N deficiency. Deficiency in available Phosphorous (P) was observed mainly in four districts and of Potassium (K) in two districts. Keeping in mind these results, the cost of phosphatic and potash fertilizers can be optimized. However, there was wide spread deficiency in secondary nutrients -- Sulphur (S) - 60-97%, Zinc (Zn) - 27-95%, Boron (B) - 12-76%,and Iron (Fe) - 1-59%. Farmers were unaware of secondary and micronutrient deficiencies and do not replenish these nutrients; this poses a challenge in terms of realizing productivity potential.

Plate 20: Collecting soil samples from pilot villages.

Results from the soil health tests were shared with various stakeholders (farmers and DoA staff) at formal and informal meetings and workshops (Plate 30). Soil health cards showing soil nutrient status, deficiency levels, and fertilizer, secondary and micronutrient recommendations were distributed to 1219 farmers.Block-specific information on nutrient status and fertilizer recommendation were summarized in wall writings for wider dissemination. Wall writings to create awareness have been completed in 8-10 sites of the pilot villages.

Plate 21: Creating awareness about the benefits of soil test-based fertilizer application through the distribution of soil health cards and wall writings in the pilot villages of Bundelkhand region

Table 59A: Soil health status of farmers' fields in Bundelkhand region

Districts	Soil pH	EC (ds/m)	OC (%)	Av P (mg/kg)	Av K (mg/kg)	Av Ca (mg/kg)	Av Mg (mg/kg)	Av S (mg/kg)	Av Zn (mg/kg)	Av B (mg/kg)	Av Fe (mg/kg)	Av Cu (mg/kg)	Av Mn (mg/kg)	No of Samples
Lalitpur	6.651	0.20	0.66	24	77	1146	206	10.7	1.20	0.4	20.7	0.75	21.9	
	(5.23-8.09)2	(0.04-1.58)	(0.11-1.7)	(5-130)	(17-698)	(353-4085)	(71-744)	(0.6-93)	(0.1-7.1)	(0.2-1.9)	(3-130)	(0.2-5.3)	(3.4-66)	179
Banda	8.14	0.18	0.51	6.3	240	2930	416	8.5	0.63	0.6	4.8	0.88	9.8	
	(6.9-8.66)	(0.08-1.01)	(0.12-1.31)	(0.7-49)	(72-1009)	(1384-4767)	(164-825)	(1.4-57)	(0.2-4.5)	(0.3-2.0)	(0.7-20)	(0.4-2.5)	(1.8-99)	160
Jhansi	7.26	0.23	0.64	15.9	91	1295	243	11.7	0.65	0.4	8.1	0.70	11.1	
	(5.49-8.16)	(0.04-1.64)	(0.23-1.37)	(0.2-58)	(22-505)	(312-5024)	(74-593)	(1.9-128)	(0.1-9.6)	(0.1-1)	(1.2-89)	(0.2-3.1)	(3.1-39)	200
Mahoba	7.60	0.22	0.57	7.8	167	3286	294	16.9	0.42	0.5	9.1	0.82	10.2	
	(5.86--8.63)	(0.06-1.01)	(0.03-1.26)	(1.5-57)	(54-469)	(1107-6090)	(72-800)	(2.5-271)	(0.1-1.2)	(0.2-1.1)	(1.4-67)	(0.3-3.1)	(2.4-53)	200
Jalaun	8.12	0.12	0.33	3.4	177	2714	402	4.6	0.35	0.6	4.6	0.81	4.9	
	6.73--8.63)	(0.06-0.32)	(0.12-0.6)	(0.1-42)	(53-371)	(1155-6565)	(101-803)	(1.0-13.6)	(0.2-1.9)	(0.3-1.1)	(0.4-39)	(0.3-1.7)	(1.3-19)	151
Hamirpur	8.26	0.23	0.45	5.8	204	3621	470	10.3	0.36	0.9	3.7	0.66	6.7	
	(7.28--9.06)	(0.11-0.65)	(0.1-1.34)	(1.0-78)	(44-988)	(1483-6494)	(164-1104)	(2.8-32)	(0.0-2.0)	(0.2-3.2)	(0.7-16)	(0.1-2.3)	(0.1-55)	129
Chitrakoot	7.93	0.15	0.43	8.6	145	2050	258	6.7	0.60	0.5	6.4	0.73	7.13	
	(7.28--9.06)	(0.02-1.81)	(0.07-1.18)	(0.8-60)	(31-780)	(695-4555)	(83-713)	(0.7-99)	(0.1-17)	(0.2-2.6)	(0.6-42)	(0.2-2.6)	(1.9-37)	200

[1]Average values;[2]Range of values.

EC= electrical conductivity;OC=Organic carbon; Av P= availablePhosphorous; K= Potassium;Ca= Calcium;Mg= Magnesium;S= Sulphur;Zn= Zinc;B= Boron;Fe=Iron;Cu= Copper;and Mn= Manganese.

Table 59B: Deficiency of nutrients in fields

Districts	Field (%)			Normal		Fields deficient in nutrients (%)									
	Acidic pH	Neutral pH	Alkaline pH	EC	OC	Av P	Av K	Av Ca	Av Mg	Av S	Av Zn	Av B	Av Fe	Av Cu	Av Mn
Lalitpur	42	49	9	100	34	0	53	50	0	70	27	76	1	0	0
Banda	0	3	97	100	49	51	0	0	0	75	68	27	51	0	1
Jhansi	6	66	29	100	29	15	28	44	0	66	63	72	12	1	0
Mahoba	3	33	64	100	34	31	0	0	0	59	85	62	21	0	0
Jalaun	0	5	95	100	94	81	0	0	0	97	95	26	59	0	5
Hamirpur	0	4	96	100	71	60	2	0	0	60	93	12	64	2	4
Chitrakoot	1	15	85	100	67	25	8	6	0	85	80	74	46	0	2

Baseline survey

Baseline characterization helps in measuring project performance towards goals and objectives. It aids the identification of existing and potential production constraintsand enables proper planning, implementation and monitoring for effective targeting of technology transfer.

A baseline survey involving 1400 households (HH) (200 /district) was carried out. A random stratified sampling approach was used to select about 10% of the households in each village. A structured questionnaire was developed and pre-tested in selected districts to ensure consistency in data collection. Nearly 35 agriculture graduates from Banda University of Agriculture and Technology were selected and trained in data collection in the seven districts (Plate 22).

Plate 22: Students of BUAT collecting household information for the baseline survey.

After critically examining the major constraints and potential opportunities, the present study has also attempted to summarize the overall key findings of the baseline survey and corresponding specific recommendations in the table below at the state level.

Key findings	Specific recommendations
1. Recurrent droughts, uneven distribution of rainfall and low groundwater potential are the major concerns	• Greater emphasis should be laid on *in-situ* and ex-situ water conservation technologies for groundwater recharge and its efficiency in use can be realized quickly. Measures to enhance water use efficiency to increase productivity need to be identified and promoted.
2. There is low adoption of improved cultivars (including drought and disease tolerant ones) of major crops like oilseeds and pulses.	• There are huge opportunities to introduce new improved cultivars both in *kharif* and *rabi* seasons to improve productivity. Appropriate local alternate seed systems need to be developed and popularized.
3. Overall the soils are low to medium fertile and there are yield gaps for major crops in majority of the pilot sites.	• There is ample scope to introduce better management practices (pertaining to soil, water, crops, IPM and micro irrigation) to improve crop yields and minimize per unit output costs. It will improve the competitiveness of our commodities in international markets.

	• Soil Health Management (SHM) & balanced fertilization strategies to build OM need to be scaled up.
4- Average milk productivity levels across the pilot sites are low at 2-4 litre/ animal/ day. It might be due to poor feeding practices and fodder scarcity in the pilot sites.	• Develop a fodder strategy for the state to be implemented in a participatory manner. • Good scope for strengthening formal market channels to sell milk and milk products in order to avoid middlemen. The total output in this sector are marketed informally.
5. Absence of commodity-based market clusters and value chains even though the district pilot sites are producing in huge quantities.	• Abundant scope for setting up infrastructure for scientific post-harvest handling of fruits and vegetables, including cold storages across pilot sites to minimize post-harvest losses.
6. Labor scarcity is the biggest challenge across pilot sites in the state. During peak agricultural operations, farmers are incurring huge expenditure on labor, which narrows down their net margins significantly.	• Huge scope to introduce and pilot ICT-based custom hiring centers across pilot sites. Fruit harvesters and power sprayers should be promoted with subsidies.

Farmer participatory field demonstrations

The baseline survey revealed that most farmers in the pilot sites cultivate low-yielding cultiva` Blackgram is largely sown in *kharif* in Bundelkhand region; whereas sorghum, pigeonpea, pearl millet and sesame are grown in Chitrakoo tmandal; and groundnut and greengram in Jhansi mandal during *kharif* season. There is an opportunity to introduce sorghum and pearl millet in Jhansi and Lalitpur as they are highly suited to the agro-climatic conditions. Introducing improved cultivars can lead to better yields. Our target was to involve 2500 farmers in FLDs in *rabi,* 2018-19 and *kharif,* 2019 with improved crop cultivars, soil test-based fertilizer application and other management practices.

Mechanization

Farmers in pilot villages follow traditional farming practices that have potential for mechanization. The fields are undulating and there is huge demand to undertake laser levelling. A large number of farmers follow the broadcast method of planting seed leading to a higher seed rate and high cost of cultivation. In Jhansi, the seed rate to grow wheat is about 80-100 kg/acre against the 40 kg/acre recommended. Machine sowing can reduce the cost of cultivation by reducing labor and input costs. Laser levelling was initiated in Jhansi and Jalaun districts in October. Nearly 60 acres were levelled between October and November, 2018. Crop sowing using the zero-till multi-crop planter and proper weed management were initiated on 50 acres in Jhansi and 10 acres in Jalaun (Plate 23A and 23B).

Plate 23A: Sowing using a zero-tillage multicrop planter after laser levelling in Jhansi

Plate 23B: (L) Before and (R) after the laser levelling undertaken in Jhansi.

Similar laser levelling work has been initiated in Banda, Chitrakoot and Hamirpur and was carried over after September, 2019 onwards.

Nearly 100-150 farmers' participatory field demonstrations on balanced fertilization application and improved crop cultivars of chickpea, field peas, mustard and wheat were undertaken in each of the Bundelkhand districts during *rabi* 2018-19. To evaluate the performance of difference crop cultivars and the impact of crop management technologies, 337 crop cutting experiments were undertaken (45-60/district) in seven districts. Results of the CCEs are summarized below.

Table 60 describes the average grain yield of chickpea, field peas, mustard and wheat obtained from CCEs undertaken during *rabi*, 2018-19. Large yield variations were seen betweendistricts. Highest grain yields were obtained in chickpea (1111 kg/acre), field peas (1275 kg/acre) and mustard (1017 kg/acre) in Jalaun district, whereas chickpea recorded the lowest yield in Banda (499 kg/acre) and Mahoba (511 kg/acre). The lowest mustard yields were recorded in Jhansi and Mahoba.

Degraded and shallow soils with poor water holding capacity was the main reason for low yields. As wheat is largely cultivated in a groundwater irrigated system, grain yield ranged between 1400 kg/acre and 1800 kg/acre (Table 60).

Table 60: Average crop yields (kg/acre) in different districts during rabi 2018-19. Figs in parentheses are the number of crop cutting experiments undertaken.

District	Average yields (kg/acre)			
	Chickpea	Field peas	Mustard	Wheat
Hamirpur	770 (10)	1002 (09)	608 (11)	1378 (11)
Banda	499 (16)	-	633 (16)	1678 (17)
Jalaun	1111 (8)	1275 (12)	1017 (10)	1377 (12)
Jhansi	834 (20)	594 (5)	288 (8)	1659 (19)
Lalitpur	743 (11)	849 (9)	568 (9)	1593 (11)
Mahoba	511 (10)	893 (5)	403 (8)	1780 (25)
Chitrakoot	819 (20)	-	566 (6)	1590 (39)

CCE results were further analyzed to ascertain the performance of different cultivars. A comparison of the performance of improved chickpea cultivars JG-11 and JG-14 and local cultivars (Fig.39a) showed the superior performance of the former in most of the districts. JG-14 was found superior as nearly 100-300 kg/acre additional gain was recorded in all districts except Lalitpur. Whereas, performance of JG-11 was found better in lalitpur with 200 kg/acre additional yield compared to local cultivar.

Performance of field peas (Prakash) was appreciated in all seven districts (Fig.39b). Nearly 200 kg/acre on an average additional yield was recorded in Hamirpur and Jalaun villages. The performance of *Prakash* in other cultivars was also found good. It was new crop introduced to farmers in Jhansi, Lalitpur and Mahoba pilot site. Lot of its production was also consumed as green vegetable (data not recorded).

Improved mustard variety Rohani gave the better yield over local cultivars in Jalaun (>1200 kg/acre vs 780 kg/acre). Performance of Rohani in Hamirpur, Mahoba, Lalitpur and Jhansi was

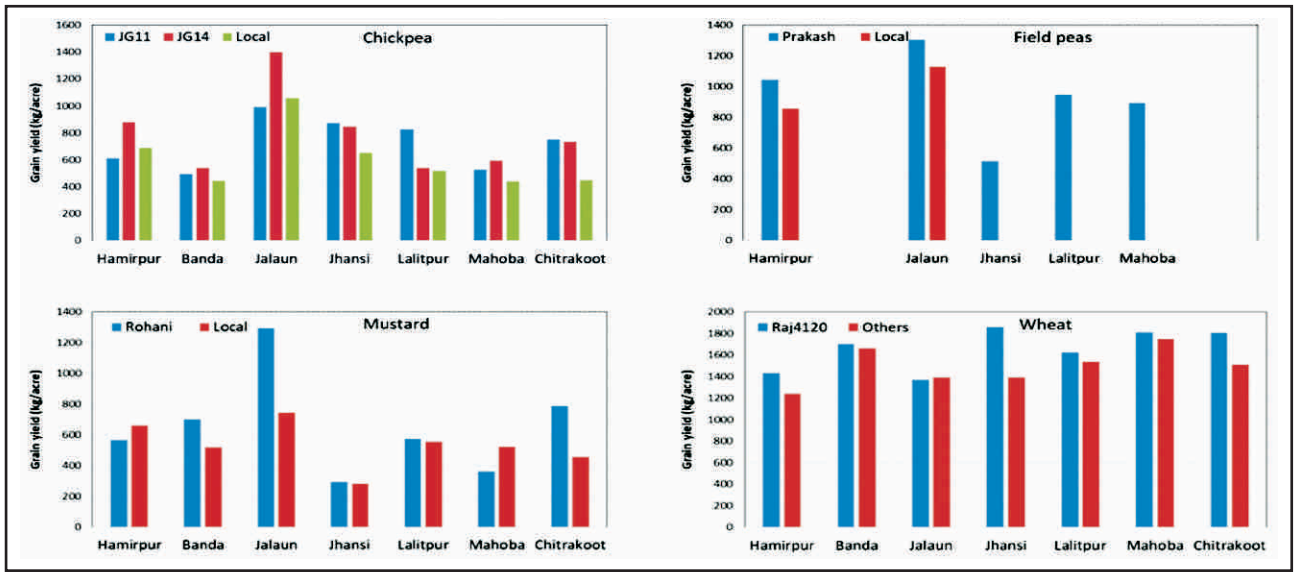


Fig.39: Grain yields of a) chickpea, b) field peas, c) mustard, andd) wheat cultivars in different districts during *rabi*, 2018-19

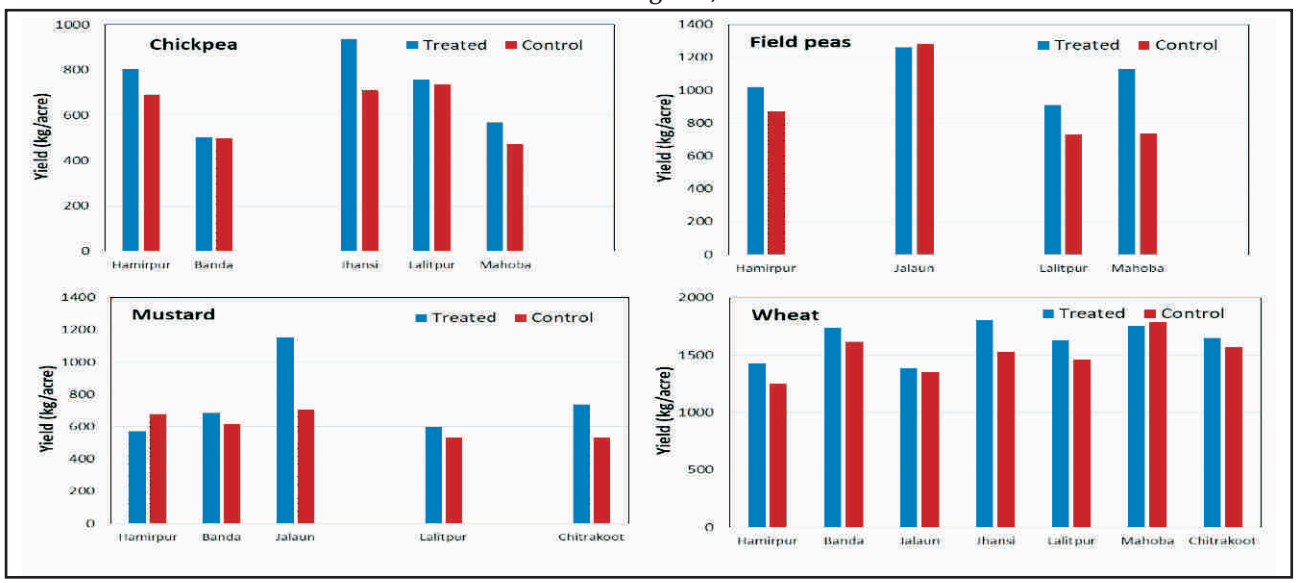


Fig.40: Yield responsesof a) chickpea, b) field peas, c) mustard and d) wheat in different districts following the application of micronutrients ($ZnSO_4$ and Boron)

found close to local cultivar (but not superior). Whereas in other districts (Jalaun, Banda and Chitrakoot), yield gain from Rohani ranged from 50 kg/acre to 300 kg/acre compared to local cultivars (Fig.39c).

Wheat cultivar Raj4120 yielded better than the local cultivars in Jhansi and Chitrakoot, with additional yields ranging from 50 kg/acre to 250 kg/acre (Fig.39d). Whereas, its performance in other districts was close to existing available cultivars (WH147, W47, Sri Ram 303, etc.).

The impact of micronutrient application ($ZnSo_4$ and boron) either as a basal dose or foliar spray compared to the control (farmers practice) was also analyzed (Fig.40). Micronutrient application gave 5-15% yield gains in pulses (mustard, field peas), oilseed (mustard) and cereal (wheat) crops.

CCE results were further summarized with four categories: (i) improved cultivar + micronutrient application; (ii) only improved cultivar; (iii) only micronutrient application; and (iv) farmer practice (control) (Fig. 41). Grain yields from treated fields were higher than that from the control. The highest yield gain in chickpea, field peas and mustard was obtained with a combination of both improved cultivars and application of micronutrients, whereas other external factors (such as irrigation) also influenced crop yields in wheat (Fig. 41).

Yield response to number of irrigation was plotted for chickpea, field peas, mustard and wheat. Yield increased with increasing number of irrigation. However, yield obtained for chickpea and mustard was optimal with two irrigations. Yields for wheat increased with increasing number of irrigations (Fig.42).

Farmers participatory field demonstration during *Kharif*, 2019

Nearly 10,000 kg seeds of groundnut, Blackgram, mung bean, sorghum, pearl millet, sesame, pigeonpea and fodder sorghum was made available to farmers in project villages during *Kharif,* 2019. Seeds were procured from various agencies (NSC, BUAT, ICAR and private institutes) such that good quality seed to be available to farmers. Nearly 300-400 field demonstrations were undertaken in each of the pilot districts during *Kharif*, 2019 (Table 61).

NRM interventions

- ***Water harvesting works***

Despite 700-900 mm of average annual rainfall, Bundelkhand suffers from water scarcity. A significant amount of surface runoff (approximately 200-300 mm/year) offers opportunities to initiate rainwater harvesting and enhance groundwater recharge. Our targeted was to construct rainwater harvesting structures based on the water balance approach. The traditional *haveli* structures have become defunct in most of the villages; these are to be rejuvenated. Check dams, gabions, farm and village ponds are targeted to be constructed/ rejuvenated based on technical/ site feasibility. ICAR-CAFRI and

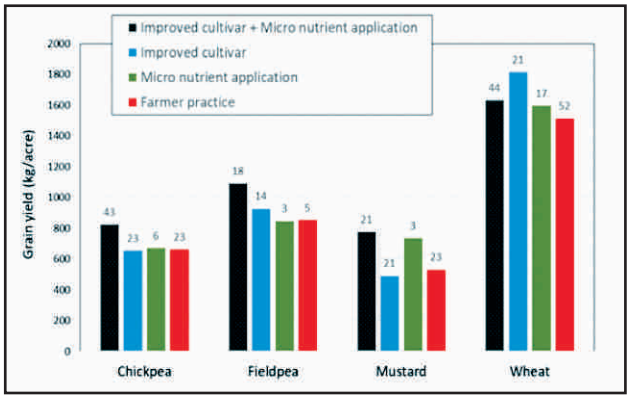


Fig. 41: Impact of improved crop cultivars and micronutrient application over compared to farmers' practices in different *rabi* crops (data compiled from all the seven districts of Bundelkhand). Values above the bars denote the number of crop cutting experiments undertaken.

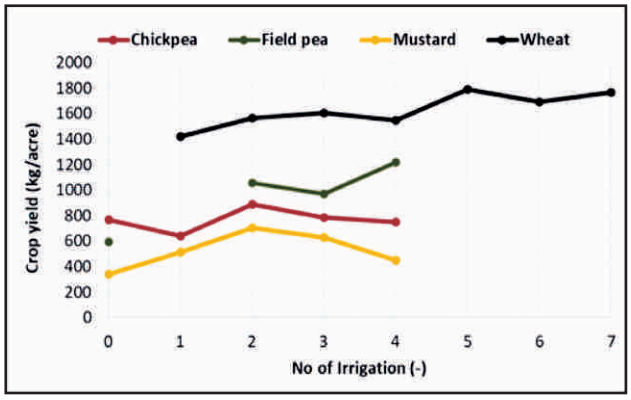


Fig.42: Yield responses to irrigation in different crops during *rabi* 2018-19 (data from 337 crop cutting experiments) in all the seven districts of Bundelkhand.

ICRISAT identified potential sites for rainwater harvesting, designed the structures and undertook construction work April 2019 onwards. Following are the water harvesting interventions undertaken to be completed before the 2019 monsoon (Table 62a & 62b).

- **Training of masons**

Construction of rainwater harvesting structures is a very specialized task and varies with land use, catchment, soil type, topography, stream dimensions and inflow availability. Water harvesting structures such as check dams, farm ponds, check walls, well recharge systems, etc. are being constructed under the watershed interventions, in addition to the renovation of traditional rainwater harvesting structures. These structures last about 5-10 years and get defunct due to damaged outlets, sliding, overturning, leakage, breakage due to tension, heavy seepage from the foundation, etc. Given the investment on it, a robust design is important.

Low-cost but robust designs for various rainwater harvesting structures were developed and tested during 2012 and 2016 at Parasai-Sindh watershed, Jhansi. ICAR-CAFRI earlier worked in Garkundar-Dabar watershed of Tikamgarh district, Madhya Pradesh and constructed several water harvesting structures during 2006-2007 which were robust, sustained heavy flooding and did not require any maintenance in 14 year.

In this project, to enhance the skills of masons in expediting the scaling up, we chose one or two masons from the districts of Bundelkhand and facilitated them to work at Jhansi (one of the pilot sites). They were given hands on training in excavation, reducing the width of the

Table 61: Farmers participatory field demonstration during *Kharif*, 2019 (Quality seed inputs provided from different sources); values shows kg seed

Crop	Variety	Source	Jhansi	Lalitpur	Jalaun	Hamirpur	Mahoba	Banda	Chitrakoot
Groundnut	TG 37-A	Nowgong Ag Prod. Pvt. Ltd	1000	1000	0	500	300	0	200
Groundnut	K6	NSC, , Anantapur (AP)	500	500			500		
Sesame	Pragati	BUAT and KVK Chitrakoot	50	20	200	100	100	100	0
Blackgram	IPU 2-43	IPU 2-43	300	100	30	50	200	20	50
Greengram	IPM2-14	ICRISAT	100	80	30	50	100	30	50
Greengram	IPM 2-3	IIPR	50	50		50	50		50
Greengram	IPM 2-14	IIPR	100		100				
Pigeonpea	IPA203 (> 220 days)	BUAT	0	0	0	0	50	50	100
Pigeonpea	ASHA/ICPH2740 (175D)	ICRISAT	0	0	0	0	50	20	100
Pigeonpea	Maruti: ICPL 8863 (165 D)	ICRISAT	0	20	50	50	0	10	0
Pigeonpea Short duration)	TS3R (135 days)	ICRISAT	0	20	20	0	0	10	0
Grain Sorghum	PVK801	Maharashtra	20	0	50	0	20	20	50
Pearl millet	HHB67-Improved	ICRISAT	0	0	50	0	20	10	50
Fodder Sorghum	CSH24MF	ICRISAT	0	20	0	0	20	0	0
Aqusap		ICRISAT	100	100	100	100	100	100	100
Humic acid		ICRISAT	200	200	200	200	200	200	200
Kitchen Garden kit		ICRISAT	50	100	100	100	100	200	100
Easy planter		ICRISAT	2	2	2	2	2	2	2
Fodder Seeds Sorghum-	CoFS-31	Maruti fodder seeds (MFS) Bangalore	24	24	12	12	8	16	8

foundation, placing iron bars, constructing various components of RWHS, avoiding preferential flow in varied situations, quality of materials required, etc., to construct check dams. A total 15 masons were trained in April 2019 at Jhansi and deputed to their respective districts to undertake water harvesting activities (Plate 24 a-d). Regular follow-ups and guidance will be provided by the ICAR-CAFRI and ICRISAT team.

Plate 24 a: The DFI project site (Jhansi) where masons were trained and simultaneously constructing a check dam in Rajapur village, Babina block

Table 62A: Water harvesting works completed by July, 2019

District	Village	Structures	Field bunding (in acres)
Jhansi	Rajapur	3 check dam with deepening of stream	80
Jalaun	Sadhara	2 *Haveli* tanks	250
Lalitpur	Pura-birdha	2 *Haveli* tanks, 1 Large pond, 1 Check dam, 3 field channels (450 m x 3 m x 1.2 m), 4 farm pond (10 mx10mx2.5m)	30
Hamirpur	Saukhar	1 *Haveli* tank	200
Mahoba	Chanda-Chandrapura		30
Banda		1 Tank (1.2 ha x 2 m), 1 *Haveli* tank	50
Chitrakoot	Rauli	1 Check dam	70

Table 62B: Details of major WHS structures along with their catchment area.

District	No	Structure	Latitude	Longitude	Catchment area (ha)	Remarks
Chitrakoot	1	*Haveli* tank	25.2053	80.7290	220	
Lalitpur	1	*Haveli* tank	25.1202	78.5396	36	Natho farmer
	2	Check dam	25.1190	78.5388	17	Yajudi farmer
	3	*Haveli* tank	25.1184	78.5402	10	Bahadur farmer
Jalaun	1	*Haveli* tank	26.0765	79.5313	256	
	2	*Haveli* tank	26.0740	79.5357	300	

Banda	1	Village tank	25.6776	80.5845	15	Baba talab
Jhansi	1	Check dam	25.4194	78.3721	44	Culvert
	2	Check dam	25.4216	78.3752	78	Bhaisasur Baba
	3	Check dam				
Hamirpur	1	*Haveli*			40	
	2	*Haveli*			150	

Table 62A and Table 62B show the number of water harvesting works initiated in the different districts along with their GPS coordinates and catchment area. For example, three check dams in series (within 1.5 km length by following the ridge to valley approach) were constructed in *Rajapur* village, Jhansi. The stream bed was deepened to increase water harvesting capacity and bunds along of the stream line were strengthened.In all the locations, one to three rainwater harvesting structures are being constructed. Field bunding work on nearly 500 acres was completed in May.

Augmenting water availability through rejuvenation of Havelis, the traditional rainwater harvesting structures

Almost every village in Bundelkhand region has long been having traditional rainwater harvesting tank system called *Haveli* cultivation. Haveli cultivation system is about 300 years old and built with nearly 50-150 m length of earthen embankment of nearly 3-7 meter width and 2-3 meter height across the slope depending on catchment area. Normally catchment of these system is in the range of 10-100 ha. Runoff generated from respective catchment was harvested during monsoon and used for multi-purpose by the village community. This was facilitating groundwater recharge and harvested rainwater was also used to provide supplemental irrigation to nearby fields during dry spells. Once the monsoons recede, the impounded rainwater used to be drained out and the tank area was prepared for cultivating *rabi* crops using residual soil moisture. Traditionally, the communities took care of the maintenance of tank bunds, desilting, repairing of water outlet periodically and scheduling of water release. Drained out water from *Haveli* system was used for pre-sowing irrigations by downstream farmers and surplus water was let out through drainage network. The productivity of *Haveli* fields was 15-25% higher in general than the nearby fields due to the deposited silt and organic matter. The *Haveli* system of cultivation is an excellent example of participatory rainwater management/collective action for managing available natural resources in Bundelkhand region. The *Haveli* system historically contributed to meet the freshwater demand in the region which has gradually become defunct largely due to disintegration of water user groups and rural institutions. This has caused heavy siltation, breached and leaky embankments and damaged outlets resulting in degeneration of the traditional *Haveli* system (Plate 24b, 24c).

Innovation

Realizing the importance of the *Haveli* structures, significant efforts were made towards their repair and maintenance in Bundelkhand region. However, during heavy downpour, earthen embankment gets eroded despite thick embankment walls, as soils in this region have poor binding ability (having courser texture and poor organic matter). Moreover, burrowing by rodents also leads to the damage of embankments. Thousands of such defunct structures are found in Bundelkhand region and these holds large untapped potential for rainwater harvesting. To address such opportunity, ICAR-CAFRI, Jhansi and ICRISAT, Hyderabad introduced the core-wall concept under the entire *Haveli* embankment wall and built safe-outlet at a suitable location to dispose-off the excess runoff along with drainage channel at the bottom of the outlet. With nearly one to two meter deep foundation, a reinforced cement stone wall is built to a suitable height for harvesting the surface runoff water. The core

wall is then covered with soil so that it is not exposed to harsh weather and its stability and lifespan is enhanced. Identification of appropriate sites, adopting a suitable design considering the location, hydrology and other safety parameters are important aspects of rejuvenating the Haveli system which are being adopted as part of the Doubling Farmer Income project being implemented by ICRISAT in partnership with ICAR-CAFRI.

Generally, *havelis* occupy only 2-5 % of the village landscape and submerge the upstream sites during the rainy season. A provision to drain water from *Haveli* structure is also given so that after the month of sept/oct, farmers can empty the tank and utilize the fields for *rabi* cultivation. It is also found that productivity of the *Haveli* fields are relatively higher as it holds more moisture/humus and other nutrients. Sites of these *havelis* are already identified by the community as it was age old practice. Therefore, no dispute arises in general to rejuvenate the *Haveli* system. Unit cost of rainwater harvesting through *Haveli* is far cheaper compared to other measures. Increased groundwater availability helps in intensifying cropping intensity to a large extent. Life expectancy of the structure is more than 50 years when constructed with stone masonry with proper provision for drain out excess rainwater. Table 63 showed that work in seven haveli structures were completed between May and July, 2019 which has created more than 300,000 cubic meter storage capacity.

Plate 24b: *Haveli* renovation and field bunding works in Sadhara village of Jalaun district

Plate 24c: *Haveli* structure from excavating foundation to various construction stage in Birdha village of Lalitpur district; Structure received good amount of runoff from upstream hillock

Plate 24d: Village tank which is renovated in Banda; Nearly one 1.5 ha area desilted and masonry outlet was constructed for safe dispose-off the excess runoff

Agroforestry

Agroforestry is an important resilience building strategy that works well without compromising production and income from the agricultural sector. It provides an opportunity to grow orchard/plantation/forest trees around the field or within fields. A comprehensive agroforestry plan has been developed. *Acacia senegal*, fruit trees (guava, fig, lemon, acid lime, moringa), ber budding and fodder grasses for *kharif,* 2019 (Table 63; Plate 25a,b,c). Nearly 85,000 plants of teak, guava, lemon, and other fruit trees were planted during monsoon period of year 2019.

Table 63: No of tree plants planted during monsoon 2019

S.No.	Fruit/ Timbler trees	Jhansi	Lalitpur	Jalaun	Hamirpur	Mahoba	Banda	Chitrakut	Total
1.	Guava lalit	350	350	350	350	400	400	120	2320
2.	Guava L-49	12	-	-	-	-	-	-	12
3.	Moringa	470	220	220	220	-	100	200	1430
4.	Custard Apple	245	220	220	220	220	220	200	1545
5.	Lime	510	500	500	500	500	500	500	3510
6.	Mango	150	150	150	150	150	150	100	1000
7.	Pomegranate	150	150	150	150	150	150	100	1000
8.	Fig	12	-	-	-	-	-	-	12
9.	Aonla	10	-	-	-	-	-	-	10
10.	Jack Fruit	20	-	-	-	-	-	-	20
11.	Bamboo	130	-	-	-	-	-	-	130
12.	Mahua	-	-	-	-	-	-	-	
13.	*Acacia senegal*	3314	3314	3314	3314	3000	2072	3314	21642
14.	Teak	5000	9000	10,500	13,500	6000	3000	6000	53000
	Total	10373	13904	15404	18404	10420	6592	10534	85631

Plate 25a: Pits excavated for developing high density fruit orchards, agroforestry plantation, teak plantation and teak around the field bunds at different districts of Bundelkhand; Team CAFRI, NGOs and ICRISAT officials making mass scale awareness campaign and monitoring the agroforestry interventions

Plate 25b: Mass scale tree plantation and awareness building organized in August, 2019; organized number of (>50) van mahotsava events across the seven pilot sites involving all community members including children, students and women

Plate 25c: Mass scale tree plantation and awareness building programs organized organized in different school premises at pilot villages during August, 2019

Workshop, field days and exposure visits

A number of workshops, field days, farmer orientation programs, farmers' days and exposure visits were organized in pilot sites from March, 2018 onwards (Table 64). This has created project awareness among farmers and developed trust among various stakeholde` Details of these events are described below:

Table 64: Workshops, field days and farmers' days organized between March and December 2018

S.N.	Date	Event type	Theme	Location	Resource person/ Institute	Targeted stakeholders	Nos. of participants
1	21-22 Jan 2019	Review-planning workshop	Doubling farmers' income in Bundelkhand region	ICAR-CAFRI, Jhansi	ICRISAT, DoA, GoUP, CAFRI	DoA officers	70
2	8 May 2019	Workshop	Quality planting material for agroforestry	ICAR-CAFRI, Jhansi	CAFRI/ ICRISAT	Farmers	100
3	17 June 2019	Workshop	World day to Combat Drought and Desertification	ICAR-CAFRI, Jhansi	CAFRI/ ICRISAT/ Forest dept., GoUP	80 Forest officers of all 7 districts	80+40 =120

Review and planning meeting: Doubling farmers' income in Bundelkhand region (21-22 January, 2019)

A two-day workshop on Doubling Farmers' income in Bundelkhand region, was organized during 21-22 January, 2019 at ICAR-CAFRI, Jhansi. The workshop started with a field visit to pilot sites at Babina block followed by project-related deliberations.

Field visit on 21 January, 2019

ICRISAT, along with CAFRI, organized a field day on 21 January, 2019 at Babina block to showcase natural resource management (NRM) interventions carried out under the DFI projects. Among those present were Dr Soraj Singhm, Director, Agriculture, UP; Dr R S Jaiswara, Director, Extension (Agriculture); Dr K V Raju, Economic advisor to the Chief Minister, UP; Dr A K Srivastava, Project Nodal Officer; Joint Director of Agriculture, Jhansi and ChitrakootMandals; Deputy Directors of Agriculture and soil conservation officers of the seven districts of Bundelkhand region; NGO representatives, Dr Sreenath Dixit, Theme leader and Head IDC, ICRISAT; district coordinators and scientific officers, ICRISAT.

Participants visited farmers' participatory field demonstrations of *rabi*, 2018 in the pilot villages of Jhansi. The interventions include laser land levelling, use of zero-till multicrop planter, improved crop varieties (chickpea JG 11 and JG 14), and the use of balanced nutrition (including secondary and micronutrients). Director, Agriculture and line department officers were pleased with the good crop growth in the demonstration fields. They interacted with farmers, field-based officers and NGO staff.

At the Parasai-Sindh watershed, which was developed by ICAR-CAFRI-ICRISAT with support from Coca-Cola India Foundation between 2012 and 2016, the visitors observed a number of water harvesting structures such as renovated *Havelis*, check dams and community village ponds. The sites selected to construct these structures and their quality were appreciated by the participants. These structures have facilitated groundwater recharge and resulted in enhanced crop intensity, improved yields and incomes. The purpose of the visit was to explore the possibility of adopting good practices that are yielding considerable benefits to farmers in DFI pilot villages. Overall, ICRISAT

and ICAR-CAFRI's efforts in providing sustainable solutions to mitigate drought-induced climate effects through an integrated watershed management approach were appreciated.

Workshop on 22 January, 2019

A formal workshop on Doubling farmers' income: planning and review was held at CAFRI, Jhansi, on 22 January 2019. Dr Sreenath Dixit (Theme leader and Head, IDC, ICRISAT) welcomed the gathering and provided a brief overview of the project, while elucidating on the workshop's objectives with partners, line department officers and field staff. Dr R S Jaiswara, director extension, DoA, GoUP, DrPooran Gaur, Research Program Director-Asia, ICRISAT; Dr Khem Chand, Director, Indian Grassland and Fodder Research Institute (IGFRI) and Dr Anil Kumar, Director, CAFRI, participated in the discussions. The team reviewed the current progress and discussed the roadmap of the upcoming NRM interventions, crop demonstrations, water harvesting, irrigation scheduling and improved method of irrigation for enhancing WUE, agro-forestry interventions, etc. (Plate 26).

Plate 26: Field visits and review workshop of the DFI project at ICAR-CAFRI, Jhansi

Workshop on "Quality planting material for scaling-up agro-forestry interventions"

CAFRI-ICRISAT and ICRAF jointly organized a one-day workshop on "Quality planting material for scaling-up agroforestry interventions in Bundelkhand region" on 8 May, 2019 and nearly 150 farmers from the seven districts participated. Only those farmers willing to adopt agro-forestry interventions in their field from *kharif*, 2019, such as teak on field bunds, high density plantation of guava and other fruit trees, were chosen and exposed to specific classroom lectures (through PPT) and taken on a field visit to CAFRI research farm (Plate 27).

Plate 27: Workshop on "Quality plant material for scaling-up agro-forestry interventions" held at Jhansi (on 8th May, 2019)

World day to Combat Drought and Desertification

World day to Combat Drought and Desertification workshop was organized at ICAR-CAFRI on 17th June, 2019. About 80 forest officers from all seven districts of UP Bundelkhand region along with 40 scientists and technical staff from CAFRI participated the event (Plate 28). Participants had a good interactive sessions about water management, drought mitigation strategy and forest plantation, water requirements of various tree species.

Plate 28: "World day to Combat Drought and Desertification" held at CAFRI, Jhansi (on 17th June, 2019)

U P Agroforestry Mission, Lucknow

NRMACAFRISOL201800300115

Establishment of Hi-Tech Nursery for the Production of Quality Planting Material

(Lal Chand, Naresh Kumar and K B Sridhar)

The main objective of this project is to establish a Hi-Tech nursery for supply of quality planting material with the capacity of production of 1.0 lakh plants. Under the project, following infrastructure has been developed during FY 2019-20:

Infrastructure development

Creation of water sources

Under the project, one rain water harvesting pond and one bore well have been developed. Water lifting and pipeline system from borewell has been installed for water supply in nursery areas and in mother blocks. A water pumping facilities from the ponds, has also developed under the project.

Installation of drip cum fertigation system: An area of 2.0 ha covered with drip cum fertigation system under the project in mother block and minor fruit germplasm block. The purpose is to improve water and fertilizer use efficiency and to reduce labour cost incurring in irrigation.

Germplasm collection and maintenance: A mother block has been established having plants of different fruit species/varieties which were collected from various sources. It includes fruit species *viz.* mango, citrus, pomegranate, sapota, guava, ber, fig, sarifa, beal, ber, jackfruit, dragon fruit etc. The block has been established on raised bed planting system following soil and water conservation measures.

Hi-Tech insect proof shade net house (02)

Under the project, two Hi-Tech insect proof shade net houses of size 40 m length x 20 width has constructed with a capacity to raise 50 thousand plants. It is designed for reducing sucking pest attack by use of insect proof netting, weed control through mulching with weed mate, enhancing the water and nutrient efficiency through micro irrigation and fertigation and fogging system to build desired humidity level as per need of propagation.

Apart from development of infrastructure facilities, the emphasis was also given on production of QPM of guava, aonla, bael, custard apple, pomegranate, fig, papaya, teak, *Acacia senegal* and other priority species**.**

Performance of newly planted fruit crops on raised bed planting system under edaphoclimatic conditions of Jhansi

An orchard of different varieties of mandarin, sweet orange, acidlime, fig, guava, mango, sapota, and pomegranate has established during February-March, 2018 on raised bed at 6 m x 6 m spacing to see adaptability of different fruit crops/varieties under Bundelkhand conditions. The promising results has been observed in terms of survival and vegetative growth parameters of newly planted fruit trees (Fig.43). Sweet orange, mandarin, acid lime, guava, pomegranate and fig has performed better in terms of survival percentage. In mango, least survival percentage (67.5%) was observed. In mango, leaf scorching on margin and die back type symptoms were reported with poor growth of the plants. Although, varieties *viz.*, Arunika, Langra and Dasheri shown very good growth.

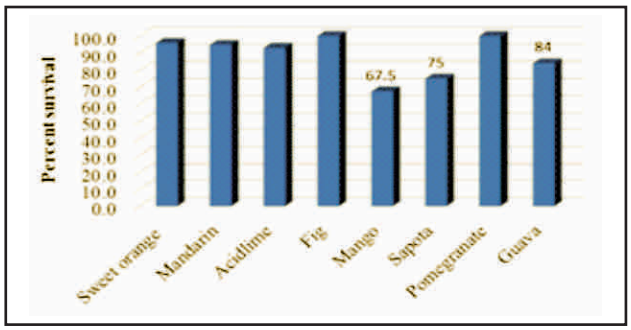


Fig. 43: Survival ability of different fruit species

The comparative mean performance of citrus group *viz.*, mandarin, sweet orange and acidlime is sown in Fig. 44. The data on growth performance of citrus groups were recorded in last week of December, 2019 in the age of two year of planting. The three citrus groups include five varieties of mandarin, five of sweet orange and eight varieties of acid lime. The maximum tree height was reported in NRCC-AL-8 while minimum in Balaji acid lime. The maximum and minimum collar diameter and canopy spread were reported in NRCC-AL-7 and Jaffa sweet

orange, respectively (Table 65). Among three citrus groups, maximum canopy spread was reported in acidlime while minimum in mandarin. Nagpur and Nagpur Seedless mandarin seems more erect growing in nature, which might be found suitable for under stroey crops in agroforestry system. Although, this is the initial performance which might give clarity in results after 4-5 years of planting.

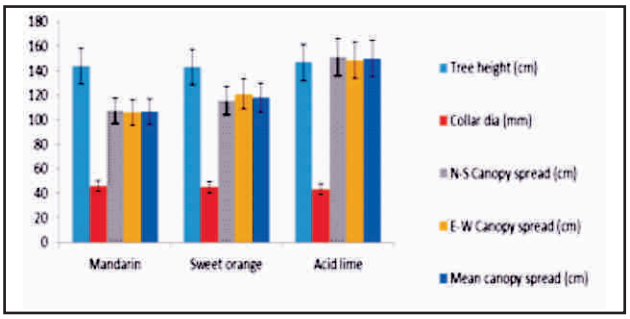


Fig. 44: Comparative growth performance of mandarin, sweet orange and acidlime

Table 65: Performance of citrus varieties on raised bed planting system under edaphoclimatic conditions of Jhansi

Citrus group	Varieties	Tree height (m)	Collar diameter (mm)	Canopy spread (cm)		
				N-S	E-W	Mean
Mandarin	Nagpur Mandarin	1.50	44.7	92.2	97.8	95.0
	Nagpur Seedless	1.63	54.1	97.8	96.8	97.3
	Clementine	1.19	36.3	90.3	93.7	92.0
	Kinnow	1.22	38.7	92.6	100.6	96.6
	Daisy	1.10	43.5	95.6	98.0	96.8
	Mean	1.33	43.5	93.7	97.4	95.5
Sweet orange	Mosambi	1.39	52.9	142.5	141.5	142.0
	Blood Red	1.40	49.6	127.0	103.5	115.3
	Jaffa	1.31	43.5	76.0	80.0	78.0
	Pusa Sharad	1.37	38.2	102.7	114.5	108.6
	Pusa Round	1.33	36.8	102.7	82.7	92.7
	Mean	1.36	44.2	110.2	104.4	107.3
Acid lime	NRCC AL-7	1.75	56.8	191.5	191.7	191.6
	NRCC AL-8	1.76	55.3	166.8	166.8	166.8
	Vikram	1.17	35.6	129.3	126.0	127.7
	Parmalini	1.38	37.6	143.5	137.2	140.3
	Sai Sharbati	1.58	41.2	155.7	153.7	154.7
	Pusa Udit	1.11	27.9	111.7	103.3	107.5
	Pusa Abhinav	1.13	36.4	143.0	135.7	139.3
	Balaji	1.06	31.6	121.6	113.8	117.7
	Mean	1.376	40.3	145.4	141.0	143.2
CV	16.2	20.0	25.6	25.6	25.3	
SEm+	5.2	2.0	7.4	7.2	7.2	

In fig, three varieties (Poona, Deana and Black Ischia) have been planted on raised bed system under drip irrigation. It has given 100 % survival under Jhansi condition with little care. The all varieties started bearing fruits after 6-7 months of planting. The trees were trained in open center system which allow more Sun light to fall on the ground and pruned in December leaving structural framework of the tree.

ICAR-ICRAF Work Plan

NRMACAFRISOL201800400116

Transforming rural livelihood and checking mitigation through agroforestry in conjunction with natural resource management in Bolangir and Nuapada districts of Odisha

(Ramesh Singh and Inder Dev)

Background information

The project entitled, "Transforming rural livelihood and check migration through agroforestry in conjunction with natural resource management in Bolangir and Nuapada district of Odisha" is the sub project of "Enabling small holders in Bolangir and Nuapada districts of Odisha to produce nutritious food through agroforestry systems". The Govt. of Odisha is the main funding agency of the project, however, the sub project is being funded by South Asia Regional Programme, ICRAF, New Delhi.

Balangir and Nuapada districts are in the western part of Odisha, lying between latitude 21° 5' and 82° 40' E. In 2006 the Ministry of Panchayati Raj has included Balangir as country's 250 most backward districts (out of a total of 640). The landscape of the districts is undulating with characteristic hillocks and experiences-tropical climate. Average annual rainfall of different districts is 1376 mm (ranging 800-1500). These districts are prone to drought and water scarcity, land degradation, poor productivity, poor permanent vegetal cover and miserable socio-economic status. In both the districts, mainly rain-fed agriculture is practiced due to non-availability of irrigation facilities. Under erratic behaviour of climatic conditions, the farmers of the region are facing crop failure very frequently. The project is being carried out with three main objectives *viz.*, to enhance groundwater recharge through suitable structures to facilitate agroforestry landuse; to improve and optimize crop and livestock productivity to check the migration and to develop model site of learning in selected patches of three villages (Plate 29-33).

Major issues to be addresses

In 2019 as per interactions with the villagers during scoping visit, we observed following points, which should be addressed for sustainable development of rural livelihoods with agroforestry at centre stage:

- Majority of the farmers are growing crops during rainy season only and keep fallow during *rabi* due to lack of irrigation water
- Open shallow dug wells equipped with pumping system is the main characteristic of resilient rain fed system. This facility is completely lacking
- Poor water holding capacity of soil
- Huge migration is in practice due to lack of employment and less remunerative agriculture
- Total amount of annual rainfall is in the range of 800 to 1500 mm, but no. of rainy days are very less (30-35 days). Higher amount of precipitation in lesser time (high intensity) causes high runoff, less groundwater recharge and base flow, land degradation, etc. High intensity rainfall should be harvested in distributed manner to mitigate its ill effect.
- Poor crop and livestock productivity was observed

Activity being undertaken

- Strengthening of earthen bunding around the agricultural field to support plantation
- Excavation of farm ponds for developing agroforestry based IFS
- Excavation of open shallow dug wells for life saving irrigation
- Plantation of identified tree species at field bunds, boundary and block plantation.
- Introduction of new crops and round the year cultivation

Interventions Implemented

- Earthen bunds around agricultural field to support plantation
- Excavation of farm ponds (25 & 6 thousand cum capacity) for developing agroforestry based IFS)

- Installation of Gauging station
- Excavation of open shallow dug wells for life saving irrigation
- Plantation of identified tree species at field bunds, boundary and block plantation-Proposed
- Introduction of new crops and round the year cultivation-Proposed

Plate 29: Interaction with the farmers at village Tara

Plate 30: Interaction with the farmers at village Chhuinara

Plate 31: Agroforestry plantation at Boirbhadi (Nuapda)

Plate 32: Various NRM activities being undertaken at village Tara in Bolangir

Plate 33: Napier Bajra Hybrid plantation on the boundary at Salandi in Bolangir

ICRISAT, Hyderabad

Enhancing groundwater recharge and water use efficiency in SAT region through watershed interventions-Parasai-Sindh Watershed, Jhansi

(Ramesh Singh, R K Tewari, Inder Dev, R H Rizvi, R P Dwivedi, K B Sridhar, Dhiraj Kumar and Mahendra Singh)

Background

Parasai-Sindh watershed has been developed by consortia of ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi and The International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad. The watershed comprises three villages namely Parasai, Chhatpur and Bachhauni and located between 25^0 23' 56" to 25^0 27' 9.34" N and 78^0 19' 45.71" to 78^0 22' 42.57" E in Babina block of Jhansi district.

Runoff and groundwater recharge, agroforestry interventions, productivity enhancement and capacity building are discussed hereunder:

Runoff and groundwater recharge

To improve the situation of water resources, rainwater harvesting to the tune of 1.25 lakh cum were created through ex-situ and *in-situ* interventions by 2015. Runoff and soil loss were gauged at 11 locations including field scale monitoring. Total rainfall during the year was 727.5 mm, 17.1% deficit over normal rainfall (877 mm). Total runoff recorded at the outlet of treated and untreated watersheds 8.17 and 11.4% of annual rainfall of 727.5mm.

All the open shallow dug wells (388 Nos.), which are only means of irrigation in the watershed were monitored for water table on monthly interval. The average water column during the year was 4.3 m. The peak discharge from treated watershed was 56% lower than untreated watershed (Fig. 45).

Development of Agroforestry Interventions

To bring more area under permanent vegetal cover, 75, 400 and 350 seedlings of lemon, karonda and *A. senegal*, respectively, were planted in the fields of 9 farmers at the field boundaries.

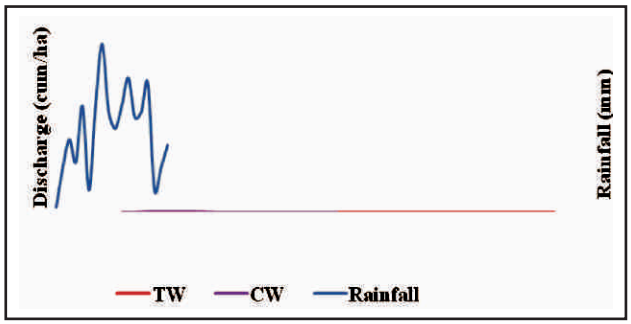


Fig. 45: Hydrograph recorded at outlet in treated and untreated area against 62.2 mm on Oct. 01, 2019

Productivity enhancement (as per farmer practice)

The major crops grown by the farmers of Parasai-Sindh watershed during the reporting year were groundnut, greengram and blackgram (*kharif*) and wheat, chickpea and mustard (*rabi*). In order to substantiate the crop productivity enhancement samples were taken from upper, middle and lower reaches of each village. 72 samples {3 (lower, middle and upper reaches) x 3 (villages) x 8 (replications)} were taken for groundnut and wheat. Twenty seven samples {3(lower, middle and upper reaches) x 3 (villages) x 3 (replications)} samples were taken for assessment of each crop of greengram, blackgram, chickpea and mustard. Each unit of sample was harvested from an area of 3m x 3m. The productivity levels recorded are presented in Table 66. The productivity of wheat, mustard and chickpea was 76, 44.7 and 43.3%, respectively, higher in treated watershed as compared to base line data.

Capacity building of watershed dwellers

Farmers of the villages Parasai, Chhatpur and Bachhauni were motivated to adopt agroforestry practices at their field by watershed team and scientists of the institute during MGMG programme. Farmers and farm women from watershed villages participated in Workshop/ Conference, Kisan Mela and Gosthi organized by ICAR-CAFRI, ICAR-IISWC, RC, Datia and IGFRI, Jhansi and also made awareness by showcasing the technologies and products of agroforestry and allied activities.

Table 66: Productivity of different crops in Parasai-Sindh watershed

Rabi, 2018-19		*Kharif*, 2019	
Crop	**Productivity (kg/ha)**	**Crop**	**Productivity (kg/ha)**
Wheat	2905	Groundnut	1485
Chickpea	1108	Blackgram	205
Mustard	1314	Greengram	195

CHAPTER

3 AICRP ON AGROFORESTRY

Research Achievements

An arboretum of different multiple purpose tree species have been established by Srinagar centre at Benhama Ganderbal with 24 different multipurpose tree species planted for ex-situ conservation. Centre evaluating germplasm of *Salix, Populus deltoides, Ulmus* and *Prunus armeniaca.* The apricot based agroforestry system revealed a good potential for the stakeholders after the completion of five growing seasons. The apricot trees recorded the maximum plant height (3.33 m), collar diameter (65.84 mm), Number of branches (18.33) and fuelwood yield 0.40 kg/ tree in combination with Orchard grass followed by tall fescue with a height of 2.96 m, collar diameter of 61.58 mm with lucerne at 2 x 3 m tree spacing. Among the four fodder species *viz.* Timothy, Orchard grass, Lucerne, Tall fescue and natural grasses (control) sown in interspaces; Orchard grass performed better with 22.80 t/ha green fodder yield followed by Tall fescue (14.50 t/ha). Centre raised five thousand seedlings of MPTS and fruit trees for distribution among farmers/tribals of Kangan (Ganderbal district) and Stakna (Leh district).

Eleven clone of *Morus alba* were analysed for growth and developmental traits by Solan centre. The study revealed that after 18 years of plantation different clones displayed their superiority for various traits. The collar diameter was maximum in the clone 7, whereas the plant height was maximum in the clone no 5. Maximum leaf yield (12.03 t/ha) was recorded in clone no. 5. Whereas, total (leaf+ branch wood) biomass (45.99 t/ha) was displayed by the clone no. 6, which was closely followed by clone no. 5. All the families of *Grewia optiva* established in the seed orchard at Nauni behaved differently. No specific trends for different seed traits have been noticed during the year under report. However, family no SO-6 registered superiority for seed length, seed width etc. Green leaf biomass (g/ plant) displayed significant variation among different family code. Maximum green leaf biomass (2366 g/plant) was exhibited by the family code CH-3, which was closely followed by SL-11(2320 g/plant) and BL-3 (1725 g/plant). In *Grewia optiva* based AF system, irrespective of lopping intensity maximum plant height (38.74 cm), number of leaves (2.78) of *Allium cepa* (onion) was found in the plant supplied with the Farm Yard Manure (FYM) on N equivalent ratio of recommended doses of fertilizers. The leaf length (35.16 cm) and the yield (27.90 g/plant) was maximum in the plants treated with vermicompost @ on N equivalent ratio of recommended doses of fertilizers. However, maximum bulb weight (27.90 g/bulb) was recorded in the plots treated with Jeevamrut. The effect of lopping intensity on plant height (cm) and number of onion leaves were non-significant. Leaf length (34.48 cm) was maximum at 75% lopping intensity. Weight per bulb (28.05 g) and total yield (10.80 t/ha) were maximum at 50% lopping intensity. An experiment was carried out to study the effect of lopping intensities- 75, 50, 25% and no lopping of *Morus alba* (M-5 clone) trees, and organic manures-vermicompost, FYM, Jeevamrut and no manure on the growth and yield behaviour of maize (*Zea maize*) during 2018-19. It was found that plant height, number of seeds per cob, dry matter production per plant, 100 grain weight, stover yield per plant & per/ha enhanced significantly with the increase in lopping intensity. Similarly, all of these traits showed their maximum values when the maize plants were supplied with vermicompost on nitrogen equivalent ratio. The level of the OC%, available N, P & K also enhanced significantly with the application of all types of the organic manure as compared to control. However, maximum returns (₹ 70,750) were calculated in the treatment involving lopping at 50% intensity and application of FYM. Under TSP about 2000 apple plants of the different cultivars were planted in the Sangla tehsil of Kinaur district of Himachal Pradesh.

Palampur centre evaluated 25 germplasm sources of *Toona ciliata* since 2006. Out of these, best 8 superior seed sources have been under field evaluation since 2012. Seed sources from Mandi *i.e.*, HPV(b) 71 is coming out to be best performing in the field followed by HPV(b) 48 and HPI(c) 22 seed source of Solan in terms of overall height gained, diameter and canopy spread. HP V(b) 71 recorded 72.41%, 69.20% and 43.12% higher height, dbh and canopy spread, respectively than HPIV(c) 87, the least performing germplasm source from Kangra. In case of *Sapindus mukorossi*, out of best performing 8 seed sources under field evaluation since 2012, AS11 from Dhraman, Sihunta Distt. Chamba was found to be the best performing in terms of growth parameters and had 23.8% and 35.29% higher height and diameter respectively than AS23 a local germplasm source from Rajpur, whereas, 50.84% higher spread was attained by another seed source from Chamba- Mangla than the local AS23 seed source. AS11 is followed by two other seed sources from Chamba- AS5 and AS3 in their growth performance. *Morus* based silvi-pastoral system has been recommended for reclamation of degraded grass lands and increasing their productivity potential in mid hills of Himachal Himalayas. Introduction of *Morus alba* (3x3m) along with the improved grasses *i.e. Setaria* and *Napier* (50x50 cm) recorded 26 and 23 per cent, respectively more total green fodder yield from the degraded land as compared to their production without tree component. Quality green fodder was obtained from tree (through pollarding at a height of 5´) and grass components, three times in a year in the months of May, July and September. Productivity of the system was enhanced to the tune of 2.83 and 3.33 times respectively as compared to the natural grass treatment. The overall net income per hectare per year of degraded grassland was raised from ₹ 5400/- to ₹ 14130/ha/year in the initial years. D & D exercise conducted by the centre in Nurpur-Valley sub regions revealed that Agri-horti-silviculture and Horti-agri-silviculture system were the most prevalent agroforestry systems. Fodder, timber & fuelwood trees are mainly concentrated on boundary of the agricultural fields. Fruit trees are either on the bunds or in the centre of the fields. When all the 21 species of trees were classified on the basis of their uses, it was seen that horticulture tree species had the highest share (52%) followed by fodder (22%), timber (13%) and fuelwood (8%) tree species. About 7 ha tribal farmers' land has been developed in district Kangra under Silvipasture and Hortipasture agroforestry systems through peoples' participation approach. Quality planting material of *Morus, Grewia, Poplar, Eucalyptus*, lemon and Galgal along with recommended fast growing grasses like Setaria were also distributed to the beneficiaries for plantation in the demonstration trials. About 0.5 ha has been adopted in village Sichling in district Lahual and Spiti under TSP programme. Three agroforestry trainings on potential and suitable agroforestry systems were imparted to 150 farmers in Mandi, Bilaspur and Shimla districts of the state under Sub-Mission on Agroforestry by the centre.

The Jammu centre initiated Poplar based agroforestry system in the Sub-tropics of Jammu and Kashmir to study the performance of *Rabi* (Potato, Spinach, Cabbage) and *Kharif* (Tomato, Brinjal, Okra) vegetables under Poplar based agroforestry system in the sub-tropics of Jammu. Growth and productivity of *Melia composita* planted at a spacing of 6×4 m after two and a half years of planting showed impressive growth performance with an average height of 8 m. Village Nanetar and Palai of Block Sumb in the District Samba adopted for carrying out TSP activities by the Jammu centre. Seed treatment drum and Knapsack sprayers were distributed in both Nanetar and Palai villages to be used by the people of the respective villages on sharing basis. Encouraging the farmers for treating seeds before sowing. Seed treatment drum uses less time and saving labour cost. Helps to boost up farm income by improving productivity. A training programme on, "Scientific benefits of Tree crop combinations" was conducted with an objective to improve the knowledge of TSP beneficiaries about scientific benefits of Tree crop combinations. It was also aimed at

providing options for diversification of existing farming systems for increased productivity by agroforestry adoption.

Kahikuchi centre is evaluating 19 seed sources of *Gmelina arborea* and the best performance for growth parameters were recorded for AAU15, AAU16, AAU17 and AAU 18 at the age of 17 years. Plant heights are 34.13, 12.69, 10.72 and 6.01% higher compared to average plant height(18.84 m) and dbh are 24.28, 24.03, 38.57 and 44.03% more compared to average dbh(31.05 cm) for AAU 15, AAU 16, AAU 17 and AAU 18, respectively. Timber volumes are 24.89, 4.38, 29.61 and 64.80% more over mean (0.912 m^3/tree) for AAU 15, AAU 16, AAU 17 and AAU 18, respectively. In *Acacia mangium* based AF system, the maximum plant height (15.37 m), dbh (32.88 cm), canopy diameter (9.18 m), timber volume (297.01 m^3/ha), tree biomass (407.08 Mg/ha) and above ground carbon stock (200.04 Mg/ha) was observed in intercrop plot at 5 x 4 m tree spacing. The maximum fodder yield of Hybrid napier (46.30 t/ha) was obtained in sole fodder followed by tree spaced at 5 x 6 m (42.90 t/ha), 5 x 5 m (38.87 t/ha) and 5 x 4 m (36.60 t/ha), respectively. Increase of OM status in soil over initial was the maximum (36.36%) in intercrop plot at 5 x 4 m after 14 years of plantation. The maximum built up of available N (28.92%), available P_2O_5 (30.85%) and available K_2O (14.00%) over initial was observed in intercrop plot at 5 m x 4 m tree spacing. Litter fall production (5.21Mg/ha) and N (38.96 Kg/ha) & P (2.82 Kg/ha) return to soil was found maximum in sole tree spaced at 5 m x 4 m. Under *Gmelina arborea* based agrisilvicultural system, the maximum height (3.45 m) and collar girth (18.53 cm) was recorded in *Gmelina arborea*. The height and collar girth of tree was 3.06 m and 17.93 cm 98.6 cm in the most promising intercrop cowpea-toria. Yield of arhar, cowpea, greengram and toria as intercrop recorded 11.0 q/ha, 8.2 q/ha, 9.0 q/ha and 9.2 q/ha respectively. Higher buildup of OM (8.96%), available N (6.99%), available P_2O_5 (13.96%) and available K_2O (5.79%) was observed in *Gmelina arborea* + greengram – Toria in third year after plantation as compared to control.

Package of Practices of eleven Agroforestry systems developed by the centre (*viz. Aquilaria malaccensis, Litsea glutinosa, Bambusa balcooa, Gmelina arborea, Azadirachta indica, Moringa oleifera, Santallum album, Tectona grandis, Michelia champaca, Dalbergia sissoo* and *Acacia mangium*) included in joint recommendation of State Department of Agriculture and Assam Agricultural University for state of Assam, during 2018-19. About 4500 seedlings of *Tectona grandis, Gmelina arborea, Azadirachta indica, Melia azadirech, Terminalia arjuna, Cassia fistula* and *Leucaena leucocephala* were produced in nursery and distributed among the farmers.

Over a period of time, the Ludhiana centre made a collection of 210 poplar clones, 35 *Eucalyptus* clones, 30 Dalbergia clones, 30 *Melia composita*, 24 *Toona Ciliata,* 12 *Moringa oleifera* and 25 Neem progenies/families. The centre recommended Poplar clones L-48/89 and L-47/88 and Eucalyptus clones C-413, C-72 and C-2045 for cultivation in Punjab. Centre standardized different Package of Practices of Poplar-Wheat based agroforestry system – Poplar clones (L-48/89 and L-47/88), spacing (8x2.5m), tree row direction (N-S), irrigation method and year-rise fertilization schedule and application method, Zn deficiency amelioration, wheat varieties (PBW 677 and PBW 725) and time of sowing under poplar (first fortnight of November). In 6-year-old Melia based system with spacing of 5 x 3 m, 7 x 3 m paired at 2.5 m and 7 x 3 m, out of five potato cultivars (7 x 3 m spacing) K. Pukhraj (11.2 t/ha) recorded significantly higher total tuber yield than Chipsona 1, Chipsona 3, Pushkar and K. Jyoti. Amongst the five cultivars of Raya, RLC 1 (1.10 t/ha) and RLC 3 (0.80 t/ha) recorded significantly higher yield than Giriraj (0.73 t/ha), GSC-6 (0.36 t/ha) and GSC-7 (0.40 t/ha). Raya cv. RLC-3 recorded minimum percent reduction (18%) in yield than open as compared to RLC-1 (27%). Amongst the six wheat cultivars *viz.* HD 2967, WH 1105, PBW 677 HD 3086, PBW 725 and PBW 658 intercropped with 5-year-old *Melia* plantation (7 m x 3 m paired at 2.5m); PBW 725 (3.16 t/ha) and PBW 677 (2.80 t/ha) recorded significantly higher yield than rest of the tested varieties averaged over both the spacings. The

yield of all the six wheat varieties was significantly higher under *Melia* 7 x 3m paired at 2.5 m spacing than 5 x 3m spacing. Application of potassium up to 187.5 kg /ha K_2O significantly increased the yield of potato. Potato yield without application of K_2O was 10.4 t/ha which increased to 13.1 t/ha at 62.5 kg/ha K_2O and 16.9 t/ha with the application of 187.5 kg/ha K_2O.

Soil organic carbon and available nutrients increased from its initial level under different spacing of poplar and *Melia* after 7 years of their planting. Soil OC, available N, P and K were maximum under 4 x 3 m spacing (4.75 g/kg, 164.3, 20.12 and 203.2 kg/ha, respectively) and minimum under 8 x 2.5 m spacing (4.05 g/kg, 149.2, 16.19 and 193.4 kg/ha, respectively) after 7 years of planting poplar. Under *Melia*, these were maximum under 5 x 3 m spacing (4.17 g/kg, 144.2, 19.27 and 196.3 kg/ha, respectively) and minimum under 7 x 3 m spacing (3.42 g/kg, 135.3, 16.24 and 188.3 kg/ha, respectively) after 7 years of planting *Melia*.

At Faizabad centre, under varietal evaluation of different intercrops, higher grain yield of paddy obtained in the variety Sarjoo-52 (1.94 and 1.81 t/ha) as compared to other varieties of paddy, whereas, higher grain yield of mustard was achieved with mustard variety NDR-8501 (1.25 and 1.13 t /ha) as compared to Kranti and Varuna under normal recommended dose of fertilizer 120:60:60 kg /ha NPK under *Dalbergia sissoo* and *C. equisetifolia* based agri-silviculture system with paddy-mustard sequence. Plantation of Guava with *Casuarina equisetifolia &* Aonla with *Dalbergia sissoo* (Ten years old) based agri-silvi-horti system and turmeric (*Curcuma longa*) as intercrop was taken separately under both *D. sissoo* and *C. equisetifolia*. This technology is being adopted by the farmers over the years. After four years and onward, Guava and Aonla are being started fruiting and after five years of plantation of *C. equisetifolia* and *D. sissoo*, farmers were able to harvest for energy purposes.

Pantnagar centre maintaining an arboretum with 96 tree species. The centre has collection of 121 clones of Poplar, 24 clones of Eucalyptus and 8 clones of *Dalbergia sissoo*. In the initial study on *Dalbergia sissoo* mortality, it was concluded that at the moleculer level stress responsive genes are not adequately expressing in declining *Dalbergia sissoo* trees. Hence due to inhibited stress responsive mechanism, important active secondary metabolites which have a role in the plant defense are not being synthesized. This conclusion is supported with the GC-MS based metabolite profiling of healthy and declining *Dalbergia sissoo* trees. Bacterial diversity in three *Dalbergia sissoo* provenances have been analysed. The soil microbial enzyme activity, metagenomic bacterial diversity and physicochemical properties indicated significant variation in phosphorous solubilizing bacteria. Use of biochar tried as growing media for clonal eucalyptus propagation. The results indicated higher rooting per cent, root length, shoot length and plant height of mini-cutting of *Eucalyptus* under perlite + pine needle biochar (50:50) followed by rice husk biochar growing media. The centre filed a Patent for "*Development of antioxidant enriched whey-based chalta (Dillenia indica L.) beverage and process thereof*". Centre generated a revenue of ₹12 lakhs during last year.

Three varieties of turmeric *viz.*, Rajendra Sonia, NDH-92 and Rajendra Sonali were grown in the interspaces of Aonla orchard at the age of 12 to 16 years at Pusa. Under 16-year-old orchard, reduction in yield of turmeric was maximum with Rajendra Sonali (53.7%) and minimum with NDH-92 (30.5%) when compared to the yield in open area. The average turmeric yield data of five years (2013-2017) indicated that NDH-92 gave the maximum yield (18.51 Mg /ha). Turmeric yield and light intensity under canopies of Aonla orchard showed highly significant and positive relationship (r^2 = 0.802** to 0.864**). The average yield data of four years indicated that the production of fruits (16.01-16.17 Mg/ha) increased upto 24-26% due to intercrops. By and large, Aonla+NDH-92 system is the most profitable on the basis of Land Equivalent Ratio (2.06), Aonla Equivalent Weight (27.17 Mg /ha) and B:C ratio (4.15).

Pusa centre has collected and evaluating eight Dalbergia genotypes and the best performance for growth was observed in genotype PS-38, PS-90, PS-20 and PS-52. Centre is also evaluating 18 poplar clones. The best performance for growth was observed in clones PP 9-OPR-1 and PP 9-J1. In *Bombax ceiba* based agroforestry system the yield of Sesamum and mustard crops and growth performance at the end of fourth year of the plantation were higher under lower density plantations (400–500 trees/ha). Sesamum showed only 7.4% reduction, whereas mustard showed 9.4% reduction in yield in agroforestry as compared to open condition. Increased volume of the trees compensated the loss of crop yield due to shading effect. Centre also estimated the growth, biomass, volume and carbon storage along an age series in *Anthocephalus cadamba* plantations planted at spacing of 5×4 m. In north-west alluvial plain of Bihar, mean annual increment and periodic annual increment both showed increasing trend up to the age of 10th year and then started to decline. Volume of the trees varied from 4.87 (8-year-pld) to 8.30 cft/tree (13-year-old). They showed the removal of 61.8 – 109.0 Mg/ha CO_2 from the atmosphere. As calculated, @ ₹ 350/cft, 500 trees/ha may give a total of ₹ 8.52 – 14.53 lakh. The centre recommended *Anthocephalus cadamba* based agroforestry system for north-west alluvial plain of Bihar at regular spacing 5×4 m and turmeric variety NDH-92 can be successfully sown in the interspaces with the spacing of 30×20 cm even up to the age of eleven year of the plantation.

In multi-location trial experiment of eucalyptus ($1^{1/2}$ years age) at Hisar planted at 8×2 m, the yield of rainy/*Kharif* (cowpea, moong) as well as winter/*Rabi* (wheat, mustard, barseem) crops in interspaces of eucalypts showed statistically non-significant differences over control. In agrisilvihorticulture system, at the age of seven years a significant increase in basal diameter and dbh of clonal (HC-2045) eucalyptus was recorded. An average increase in height of 1.3 m was also recorded. Significantly higher grain and straw yield of wheat was observed in agrihorticulture system as compared to agrisilvihorticulture system. However, grain yield of wheat under agrisilvihorticulture and agrihorticulture system reduced up to 67.3 and 58.8 per cent, respectively over control (sole wheat without trees). Maximum grain and straw yield of barley was found in the interspaces of clone -83 followed by C-7. The average reduction in grain and straw yield of barley under eucalyptus (planted in Feb., 2015) based agroforestry was 14.0 and 30.1 per cent, respectively over control (sole barley without trees) after 3 years. In three years old poplar planted at 5×3 m spacing, maximum grain (4.92 t/ha) and straw (5.51 t/ha) yields were recorded in WH-1105 being statistically at par with HD-2967 but significantly higher than WH-711. Recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the grain as well as straw yield over recommended dose of fertilizer in all the varieties of wheat. Two years old poplar and eucalypts planted on field bunds has not been found to affect the yield of sorghum and barley/wheat even near the tree line.

Progenies of 18 CPTs of *Melia composita* exhibited significant variability *w.r.t* growth characters in the field after three years of transplantation. The plus tree progeny MCB2 from Haryana exhibited highest diameter at breast height followed by MCPAU2 and MCS6 from Punjab and Himachal Pradesh, respectively. Fourteen clones from University of Horticulture & Forestry, Nauni, Solan were also transplanted in research field for multiplication trial at a spacing of 5×3 m following randomized block design with four replications. Among different clones, clone-1007 observed to be fastest growing which showed the highest growth with respect to plant height (14.8 m). The basal diameter (20.5 cm) and dbh (15.3 cm) was recorded maximum for 5503 and 9607 clones, respectively. Coordinated trial of shisham with eight clones was established and the significant variability for growth traits was observed among the clones. After 18 months of transplantation, the plant height differed significantly and ranged from 3.4 to 4.3 m with the general mean of 3.7 m. The highest basal diameter (3.4 cm) was observed in clone in PS-38

closely followed by L-5 and L-1 and lowest (2.0 cm) in PS-54.

After eight years, higher B: C ratio of 1.98 and 2.22 was found in poplar based agroforestry planted at 10 ×2 m spacing with cowpea-wheat and sorghum-berseem rotation, respectively over 5 ×4 m and 18×2×2 m spacings. Growing of sole poplar is not economical as compared to poplar with agricultural crops.

Seven entries of *Gmelina arborea* were collected at Bhubaneswar from the eastern parts of India for evaluation of growth and biomass production. At 42 months after planting, Durgaprasad (Nayagarh, Odisha) entries recorded highest plant height (2.98 m), basal girth (17.75 cm) and crown spread (1.73 m). However, the performance of Badakameti (Nayagarh, Odisha) was lowest with respect to plant height, basal girth and crown spread among all the seven tested entries. *Acacia mangium* were collected from nine provenances and planted and after 30 months of planting Villigram entries was significantly superior with respect to plant height (12.02 m) DBH (8.48 cm) and crown spread (3.47 m). In guava based agrihorticultural system, the nutritional treatment, (STD (100%) + FYM + Biofertiliser) in guava + arrowroot gave highest guava fruit and fresh arrowroot yield, 2628 kg/ha and 6568 kg/ha respectively with the net return of ₹ 64338 and 2.19 benefit cost ratio. This higher yield of these both crops in the system might be attributed due to balanced nutrition of arrowroot and guava. This system also recorded highest available N (264.5 kg/ha), P_2O_5 (79.5 kg/ha) and K_2O (259.7 kg/ha) in the same treatment (STD (100%) + FYM + Biofertilizer).

Guinea is the most productive and profitable fodder crop irrespective of associated silvi trees in the silvipastoral systems. Maximum fodder yield was obtained from Guinea 20.9 t/ha in association with *A. mangium* with BCR 2.8 and fodder yield recovery percentage over sole was highest in Guinea (79.9) followed by thin Napier (75.2) & Setaria (74.3). Analysis of soil after three cuttings per annum of the fodder crops in silvipasture system indicated highest values of available N in Setaria, available P_2O_5 in thin Napier and available K_2O in guinea plant. *Gmelina arborea* with intercrops (greengram-toria) at 30 months after plantation recorded highest plant height (2.72 m), basal girth (23.2 cm) and crown spread (2.07 m), followed by *G. arborea* with cowpea-toria. In this agrisilvi system, after harvest of intercrops indicated that the highest value of soil available N (229.1 kg/ha) and K_2O (105.3 kg/ha) with greengram-toria followed by cowpea–toria. Among the *G. arborea* based agrisilvicultural systems, *G. arborea* + cowpea-toria recorded the highest arhar equivalent yield of 1146 kg/ha and the net return of ₹ 36,700/ha and BCR of 1.66 followed by *G. arborea* + Arhar (Net return ₹ 27,400 and BCR 1.78).

Under TSP programme by the centre 35 no of tribal families of Majhisahi village, Dhenkanal Sadar block in Dhenkanal district were benefited. Total 25.0 ha of cropped area in the village were covered under different livelihood and nutritional security practices with seven number of front line demonstrations, three trainings and one exposure visit. On an average per farmer per year achieved ₹ 25,000-35,000 with an additional engagement of their own family member of 35-100 days. Animal components like poultry and goat with community pisiculture gave them higher profit and more engagement followed by horticultural interventions like vegetable cultivation and orchard management of mango and cashew.

In evaluation of 18 germplasms of *Gmelina arborea* at Jhargram for genetically superior mother and establishment of seed orchard, 6 nos. of superior germplasms were selected on the basis of their growth parameters. In evaluation of 28 nos. of germplasms of *Acacia auriculiformis* 8 nos. of superior quality were selected. The centre evaluating 12 seed sources of *Gmelina arborea* and the best performance for growth parameters were recorded for Acc. No. 6, Acc. No.11, Acc. No. 12 and Acc. No. 5 at the age of 14 years with 62.6, 56.9, 22.5 and 6.1% higher timber yield, respectively, over the average (0.89 m^3/tree) due to 24.5, 29.9, 8.8 and 2.0% more dbh, respectively, than the mean (14.7 cm). The evaluation of 6 seed

sources of *Acacia auriculiformis* for growth parameters at the age of 16 years showed good performance for Acc. No. 4, Acc. No. 1 and Acc. No. 7. Plant heights are 6.8, 2.8 and 2.8% higher compared to average (17.7 m) and dbh are 25.5, 0.0 and 1.9% more compared to average (26.7 cm) for Acc. No. 4, Acc. No. 1 and Acc. No. 7, respectively. Timber volumes are 69.55, 7.70 and 3.10% more over mean (0.474 m3/tree) for Acc. No. 4, Acc. No. 1 and Acc. No. 7, respectively.

The highest timber yield (0.119 m^3/tree) of *Gmelina arborea* was in combination with sweet orange + cowpea-toria and that combination yielded maximum sweet orange fruits (994 dozen/ha) also. Arhar equivalent yield of different intercrops studied as alley crops in gamhar – sweet orange plantation, were 19.50 q/ha, 18.00 q/ha and 14.80 q/ha, in cowpea – toria, greengram – toria and arhar, respectively. Cultivation of cowpea-toria sequence as intercrop has also resulted buildup of OC (4.9%), available N (8.8%), available P_2O_5 (17.1%) and available K_2O (5.7%) along with additional net return of ₹ 14140/- from alley crops in the second year. This intercropping sequence as alley crops has also intercepted 2.56% higher light resulting 7.62% extra biomass production and 7.53% carbon sequestration in gamhar and sweet orange-based agroforestry system.

In order to identify the appropriate land use system towards enhancing productivity of marginal lands under rain fed conditions, an effort was made to develop agroforestry system integrating the arable crops, fruit trees and silvi components for rainfed upland under red & laterite tract of humid & sub-humid zone. The highest timber yield (0.095 m^3/tree) of *Gmelina arborea* was in combination with sweet orange + cowpea-toria and that combination yielded maximum mango fruit (6.8 t/ha) also. Arhar equivalent yield of different intercrops studied as alley crops in gamhar – mango plantation, were 19.50 q/ha, 18.00 q/ha and 14.83 q/ha, in cowpea – toria, greengram – toria and arhar, respectively. Cultivation of cowpea-toria sequence as intercrop has also resulted build-up of OC (6.78%), available N (3.60%), available P_2O_5 (2.41%) and available K_2O (2.96%) along with additional net return of ₹ 14935/- from alley crops in the second year. This intercropping sequence as alley crops has also intercepted 2.41% higher light resulting greater biomass production and carbon sequestration in gamhar and sweet orange-based agroforestry system.

In *Eucalyptus tereticornis* and mango - based agroforestry system, highest timber yield (0.770 m^3/tree) of *Eucalyptus tereticornis* was in combination with sweet orange + arhar and that combination yielded mango (6.6 t/ha) also. Arhar equivalent yield of different intercrops studied as alley crops in gamhar – mango plantation, were 19.50 q/ha, 18.00 q/ha and 15.2 q/ha, in cowpea – toria, greengram – toria and arhar, respectively. Cultivation of cowpea-toria sequence as intercrop has also resulted buildup of OC (1.61%), available N (0.57%), available P_2O_5 (2.61%) and available K_2O (3.26%) along with additional net return of ₹ 15833/- from alley crops in the second year of the experiment. This intercropping sequence as alley crops has also intercepted 1.18% higher light resulting 38.12% higher biomass production and carbon sequestration in gamhar and sweet orange-based agroforestry system.

Under evaluation of *Gmelina arborea* based Agrisilvicultural System at Ranchi, the average maximum height of *Gmelina arborea* was observed in combination with GA+ Arhar (Var. Vishal 120) height (130 cm) and maximum average diameter 35.71 mm in *Gmelina arborea* + greengram in the second year 2019. The average maximum height (173.33 cm) and maximum average collar diameter (23.92 mm) of *Melia azedarach* was observed in Sole *Melia azedarach* in the second year. Under TSP centre distributed and planted *Tectona grandis* (1,500 nos.), *Gmelina arborea* (1,500 nos.), *Melia azedarach* (1,000 nos), *Mangifera indica* (3,000 nos) and *Psidium guajava* (1,000 nos) in the tribal farmer's field

Ailanthus excelsa germplasm evaluation studies in rainfed condition at SK Nagar revealed that among the thirty germplasm evaluated Mithivavadi and Jagudan villages seed sources are the best performing in terms of growth parameters *viz.,* plant height (9.93 m) and collar

diameter (25.8 cm) after eight years of plantation. Collar diameter of different germplasm ranged between 16.72 to 25.8 cm significant difference among the ten elite progenies of neem along with a local check was observed, for their growth parameters in the multi locational trial. After fourteen years of plantation. Progeny No 110 gave significantly highest plant height (8.39 m) and collar diameter (25.73 cm) over rest of the progenies. The *Melia* species evaluation studies revealed that genotype MD 05 performing better in terms of growth parameter *i.e.* plant height (5.18 m), collar girth (37.36 cm) and collar diameter (11.90 cm) and it was followed by MD 01 Clonal source received from Mettupalaym.

In case of alternate boundary of neem and *Ailanthus,* the highest grain (250 kg/ha) and straw yield (600 kg/ha) of pearlmillet was observed in middle side and it was followed by north side, west side and the lowest yield was obtained in east side. The grain yield of amaranths (485 kg/ha) was recorded maximum in middle side and it was followed by west side and north side. Alternate boundary plantation of *Ailanthus* and neem showed that the highest plant height (11.62 cm) and collar diameter (40.13 cm) of *Ailanthus* and plant height (7.04 m) and collar diameter (15.86 cm) of neem were observed in south side of the field. The centre produced 7000 plants of different MPTs and Medicinal tree species in the agroforestry for supplying to the farmers. Under Tribal Sub Plan (TSP) tribal farmers adopted different agroforestry systems *viz.,* boundary plantation, horti pastoral systems, vadi project etc and farmers were provided improved seeds of various intercrops (castor, moongbean, clusterbean and oat), fertilizers, castor cake, insecticides (Chlorophyriphos) and fungicide (COC) to the selected farmers of Vagdadi villages.

Fatehpur Shekhwati centre evaluating 13 provenances, 15 plus trees and 120 CPT's of *P. cineraria collected from* Gujarat and Rajasthan. Under block plantation evaluation, four tree species *viz.*, *P. cineraria, A. nilotica, A. tortilis* and *H. binata* were planted at 5 m x 5 m in block n the plantation. Data revealed that *A. tortilis* registered maximum tree volume 0.72 m^3/tree followed by *P. cineraria* 0.25 m^3/tree and *H. binata* 0.22 m^3/tree after 22 years. In rainfed condition experiment under 22 year old *P. cineraria* based agrisilviculture system highest yield (710 kg/ha) was recorded in clusterbean (RGC 1066) variety and lowest yield (340 kg/ha) was recorded in Moth bean (variety RMO 435) and significant variation were seen between crop varieties in comparison to control (without tree). The Agrisiviculture enrich the soil fertility status in the form of organic carbon and available N, P and K. Organic carbon in the soil, increased from 0.24 to 0.33 per cent under this system in rainfed condition of arid climate. silvipasture systems in dry semi-arid condition maximum green fodder yield of *C. ciliaris* recorded with *P. cineraria* tree 265 q/ha followed by *Tecomella undulata* 2300 q/ha, *A. indica* 165 q/ha and *H. binata* 155q/ha. This year 28 ha demonstrations of Moong based agroforestry system were established under TSP in Banswara district and two trainings were organized. All tribal farmers were provided input such as moong seed, fertilizers (NPK and Urea), fruit plants (Mango, lemon and pomegranate) and insecticides and pesticides.

Nagpur Centre collected and evaluating 13 *Ailanthus excelsa* accessions. The best performance for growth was observed in accession No. ACN/MHK/4 and ACN/MHK/1. The wood volume of ACN/MHK/4 was observed 30% higher compared to provenance No. ACN/MHK/10. Centre also collected, screened and evaluating six *Tectona grandis* accessions and observed that PDKV/AF/1 and PDKV/AF/2 were promising. The DBH of PDKV/AF/2 was observed 33% higher compared to seed raised local teak accession. The centre is having germplasm of twenty bamboo species, out of which *Dendrocalamus stocksii, Bambusa bambos, Bambusa tulda, Bambusa balcoca* performing better on biomass basis and identified as promising for cultivation in hot and dry agroclimatic conditions in the Vidarbha region. Centre recommended VANWADI model for paddy growing region. It consist of growing

of 300 teak trees/ha on paddy bunds and 30 mango trees/ha under paddy farming. Centre has developed Hi-tech nursery complex for production of quality planting material of medicinally useful trees for afforestation in the region. Fifty thousand saplings were supplied for massive afforestation programme of Maharashtra state. Centre also contributing in State Agroforestry Mission and planned to raise the Clonal nursery for mandatory species *Teak, Ailanthus and Bamboo.*

In provenance trial of *Dalbergia sissoo* collected from seven provenances by Jabalpur centre, at the age of 8½ years, provenance received from ICAR-CAFRI, Jhansi (T_7) recorded higher plant height (794 cm) and basal diameter (153 mm) and dbh (124 mm). Under 20 years old agrisilviculture system (*Dalbergia sissoo* + Paddy-Mustard/ Gram/Wheat rotation) where 4 pruning treatments (*viz;* no pruning, 25%, 50% and 75% pruning) and three crop rotation (Early paddy (Danteshwari) + Mustard], [Medium paddy (MTU-1010) + Gram], [Late paddy (Kranti) + Wheat]. Significant maximum grain yield of paddy was recorded under open condition (2241 kg/ha) at par with 75% pruning (1767 kg/ha). No pruning recorded significantly lowest grain yield (1198 kg/ha) at par with 25% pruning (1328 kg/ha) and 50% pruning (1530 kg/ha). Managed agroforestry system (*i.e.* pruning treatments) recorded higher monetary return (₹ 55815 /ha) as compared to crop alone (₹ 23092 /ha) and tree alone (₹ 41017/ha). During *rabi* season crops *viz.*, mustard, gram and wheat were sown after paddy. Significantly higher wheat equivalent yield (9719 kg/ha) was recorded under open condition and was significantly superior to all the pruning treatments. No pruning recorded significantly lowest yield (3957 kg/ha). Significantly maximum net monetary return was recorded under *Dalbergia sissoo* + medium paddy (MTU-1010) + Gram (₹ 71087/ha) crop rotation followed by *Dalbergia sissoo* + late paddy (kranti) + wheat (₹ 60370/ha). *Gmelina arborea* based agrisilvicultural system where *Gmelina arborea* + greengram -toria treatment recorded the highest arhar equivalent yield of 1529.3 kg/ha as compared to sole arhar (772.2 kg/ha). Among the *Gmelina arborea* based agrisilvicultural system, *G.arborea* + greengram - toria recorded the net return (₹ 38465/ha) and B:C ratio (2.26) as compared to sole arhar in terms of net return (₹ 26473/ha) and B:C ratio (2.04). Studies showed that agrihorticulture system (Aonla + Wheat) was more profitable (₹ 44520/ha) as compared to wheat alone (₹ 30410/ ha). The B:C ratio of Agrihorticulture system was more (2.23) as compared to growing of crop alone (1.90).

At Rahuri, eight entries of *Acacia nilotica* var. indica were selected from 61 accessions collected from different locations of Maharashtra. The *Acacia nilotica* provenance RHRAN-36 recorded significantly highest plant height (8.97 m) but at par with all the entries studied. The entry RHRAN-57 recorded significantly highest collar diameter (22.30 cm) and DBH (17.27 cm) but at par with all the entries. The entry RHRAN-6 recorded significantly highest bole height (2.76 m) whereas the entry RHRAN-41 recorded highest number of branches (4.95).

Effect of planting geometry on productivity of Teak under agroforestry system in semi-arid condition revealed that the growth parameters *viz.*, plant height, collar diameter, crown spread (East, West) and (North, South) of teak plants ranged from (202 to 248, 3.55 to 5.8, 71.5 to 125.6, 78.4 to 135.8 cm) respectively. The litter fall ranged from (109 to 121 kg/ha) maximum plant height was recorded under (Teak + cowpea + mulching - fodder). Whereas collar diameter, crown spread (East, West) and (North, South) was more under treatment Teak sole – (8x2x2 m Paired row) (5.8,125.6, 135.8 cm), respectively. Maximum litter fall was observed under treatment Teak sole – (8 x 2 x 2 m paired row). Among the intercrop treatments maximum plant height (248 cm) collar diameter (5.07cm) and litter fall (120 kg/ha), was recorded in treatment (Teak + cowpea + mulching – fodder maize). The grain and straw yield was highest in sole treatments of Cowpea and Blackgram 15.91 and 12.08 q/ha. Among intercrop treatments grain and straw yield was recorded more under treatment (Teak + Cowpea + mulching - Fodder Maize) (15.88 qtls and 30.48 q/ha) respectively.

In regards with *rabi* season, the sole crop fodder maize (Sole crop Blackgram - fodder maize) recorded higher fodder yield (665.55 q). Among intercrop fodder treatments Teak+Blackgram mulching + fodder maize recorded higher maize fodder yield (486.80 q). Land equivalent ratio for *kharif* pulses was more in treatment (Teak (Paired row) 8 m x 2 m x 2 m + Cowpea + mulching - Fodder Maize (1.0) and for *rabi* fodder, intercrop treatment (Teak Paired row 8 x 2 x 2) + Cowpea - Fodder sorghum (0.74).

The Hyderabad centre evaluating Neem and Pongamia germplasm. There are 49 neem lines and 29 Pongamia lines available at the centre. Among the neem lines since 2002, Line 42 recorded higher growth parameters like height (13 m) girth (75 cm) at the age of 16 years, which is 33% higher in height and 17% higher in girth compared to control. In multi-location trial since 2004, Line 117 recorded mean plant height (7.8 m) followed by Line 115 (7.7 m) followed by girth (78 cm, 68 cm) respectively which is 12.8% and 20% more compared to control. In Pongamia germplasm lines since 2004, Line SRJ-39 recorded higher growth parameters like height (7.7 m) girth (66 cm) at the age of 14 years which is 25% higher in height and 28.7% higher in girth compared to control. Two clones from Mettupalayam (Clone-1, Clone-2) along with different inter crops were evaluated. Highest grain yield was recorded with foxtail millet (795 kg/ha) followed by pearl millet (650 kg/ha). The gross and net returns were not influenced by different clones. However, clone-II recorded higher gross (₹ 10,036/ha) and net returns (₹ 5036/ha). Among the inter crops, Blackgram (₹ 20,332/ha, ₹ 12,223/ha) followed by greengram (₹ 15,750 and 3250/ha) recorded significantly higher gross and net returns with B:C ratio (1.71) followed by foxtail millet inter cropping (1.39).

In nutrient management of Maize-Redgram sequence in Mango based Agri-Horti system, significantly higher maize grain yield (5535 kg/ha) and stover yield (9724 kg/ha) was recorded with 125% RDF (275-75-62.5 NPK kg ha), which was at par with application of 75% RDN + 25% N through Poultry manure (4596, 8044 kg ha) and sole crop. The higher net returns by entire system with 125% RDF (₹ 50,355/ha) with B:C ratio (1.98) which was at par with 100% RDF (₹ 44,504/ha) with B:C ratio (1.88) and 75% RDN 25% N poultry manure (₹ 40,206/ha; 1.48). In Custard apple based horti-pastoral system the fruit yield of custard apple was not influenced by type of grasses, or nutrient management practices (1800-2400 kg/ha). Dry and fresh herbage yield was significantly influenced by type of grasses. Significantly higher fresh and dry herbage yield was recorded with *Cenchrus cililaris* (14.3, 4.5 t/ha) followed by *Panicum macimum* (10.1, 3.06 t/ha). Among the nutrient management practices, higher fresh and dry forage yield was obtained with 100% RDF + 10 t FYM/ha). Crude protein was higher (13.2%) and crude fibre was lower (19.4%) in Hedge Lucerne.

Dharwad centre is evaluating 20 provenance of Neem, the performance of two provinces *viz.*, Vijayapura and Raichur were superior over other clones. In tamarind 14 collections were evaluated after 19 years, NTI -80, NTI-14 and SMG-13 recorded higher fruit yield by 25 to 35% as compared to local. The superior clones were propagated for demonstrations purpose in the farmer field.

In Sapota-Timber species based agroforestry system, the height and DBH were significantly higher in the *Pterocarpus marsupium* (12.2 m and 34.25 cm) and lowest in the *Lagerstroemia lanceolata* (9.78 m and 23.25 cm) when compared to other tree species. The height of Sapota was significantly higher in association with Sapota + *Lagerstroemia lanceolata* followed by Sapota + *Pterocarpus marsupium* as compared to sapota with other tree species. Fruit yield of sapota was significantly higher when sapota grown alone (32.98 kg/plant) followed by Sapota + *Pterocarpus marsupium* (20.27 kg/plant) and Sapota + *L. lanceolata* (21.15 kg/plant) followed other tree species. Soil chemical properties indicated that, the organic carbon was higher in *Sapota* + *Tectona grandis* + FC (5.1 g/kg) followed by *Sapota* + *P. marsupium* + FC (4.9 g/kg) as compared to other agroforestry systems. Among Nitrogen and Potassium had higher in *Sapota* + *Tectona grandis* + FC (239 and 428 kg/ha, respectively) whereas, available Phosphorus

had maximum in *Sapota* + *P. marsupium* + FC (53 kg/ha) agroforestry system as compared to initial status of the soil.

Among the seven fodder tree species evaluated under agroforestry system maximum dbh was recorded in the *Moringa olifera* (8.73 cm) and *Leucaena leucocephala* (7.90 cm). Number of branches was significantly higher in *Leucaena leucocephala* (23.01) followed by *Glyricidia sepium* (20.93) and *Calliandra calophryus* (18.21). The green biomass was significantly higher in *Calliandra calophryus* (1325 kg/ha) and *Leucaena leucocephala* (1225 kg/ha) as compared to other fodder tree species. Maximum Soybean grain yield was higher when soybean grown with *Albizzia lebbeck* (530.70 kg/ha) followed by *Calliandra calophryus* (482.20 kg/ha) when compared to other fodder tree species. Tamarind – Curry leaf based Agroforestry system is recommended by the University for inclusion of package of practice. Centre has established "Biofuel Park" funded by Karnataka State Bioenergy Development Board in which centre has planted Biofuel seedlings of six species. Centre has also collected and raised germplasm of twenty rare, endangered and threatened (IUCN, RET) species collected from various places of Western Ghats and planted in the same area. During the year, 2000 kg of Neem and 4500 kg Pongamia seeds were procured by the centre and produced 1176 kg of Neem cake, 2806 kg of Pongamia cake, 500 ltr. of Pongamia oil, 125 ltr. Biodiesel and 20 ltr. of Biphenyl.

FCRI, Mettupalaym centre prioritized ten different tree species including two mandated species allotted to the centre namely Melia and Ceiba. Over five hundred genetic resources in the form of provenances/seed sources/ progenies/clones are assembled and are incorporated in various forms under different agroforestry systems. Centre released *Melia dubia* MTP 2 as a potential and High Yielding Short Rotation (HYSR) clone with a productivity potential of 100 tons per ha within a short period of 18 to 24 months for utilization as a raw material for pulp and paper industry. The same clone after 48 months is amenable for plywood production due to its higher veneer recovery (over 62%). Centre developed a potential clone in Kadam (Kadam MTP 1) and is released as variety through state variety release committee. This clone is HYSR clone and exhibited a production potential of over 135 tons per ha in three years. The clone is suitable both for paper and plywood production. A promising clone in Ceiba – Silk cotton (MTP CP 18) has been identified by the centre as a high yielder and amenable for introduction into dryland condition.

Mettupalayam centre developed an innovative mini clonal technology for Melia, Kadam, Casuarina, African Mahagony and Teak which is one of the pioneering attempts in the country and ensures rapid multiplication of elite genetic resources. A unique and innovative multifunctional AF model has been designed in 0.75 acres incorporating 28 tree component, four annual components and two animal components. The one year of development and evaluation has indicated that this Multifunctional Agroforestry model is able to generate an income of ₹ 550 to 1000 per day to the farmers which has an excellent replication potential across the country and satisfy the demand of doubling the farmer's income as envisaged by the Govt. of India.

This centre has created an innovative institution called Consortium of Industrial Agroforestry (CIAF) and linked all stakeholders in one platform. This consortium is involved in resolving all the issues and constraints in the entire production to consumption system in Agroforestry. During the last four years the Consortium is able to develop over 30000 acres of organized Industrial Agroforestry plantations in association with plywood, pulp and paper, match, timber and dendro power industries. The consortium also facilitate availability of quality seedlings, plantation development, plantation felling operation and marketing of farm grown trees through an innovative consortium approach. The assurance of buyback, insurance and credit facility are the salient activities of the consortium.

The centre has also credential of establishing India's first Agroforestry Business Incubator and

caters to the needs of skill and entrepreneurship development. Since its launch in February, 2019, this Business Incubator has commercialized two clones Kadam MTP2 and Casuarina MTP. Centre addresses the issue of the availability of quality seedling production through Venter Capital Scheme and supplies over one lakh clone annually, to the farmers. Over one thousand five hundred beneficiaries representing farmers, forest department officials, tribal communities, nursery growers, value addition industries, PC's of KVK, members of CIAF and Business Incubatees are trained towards skill and expertise development in Mini Clonal Technology, Briquetting Technology, Industrial Agroforestry, Precision Silviculture, Multifunctional Agroforestry and Supply chain management and involved in professional man power development in Agroforestry sector.

The Thrissur centre is evaluating 10 provenances of *Acacia mangium* collected from their natural ranges in Australia and Papua New Guinea and the best performance for growth parameters were recorded for Papua New Guinea provenances like Kuranda, Arufi Village and Upper Aramia at the age of 17 years, which is 60-70 per cent more compared to Australian and Kerala provenances. The centre is also evaluating 30 different teak accessions from South India of which the better ones were from Nilambur region, which is around 80-90 per cent better than other provenances at the age of 17 years.

Studies related to find out suitable silvopastoral system, the integration of protein rich mulberry hedgerows in coconut garden provides an excellent option to enhance quality forage production and carbon sequestration in humid tropics of Kerala. Mulberry fodder banks yielded maximum dry forage (32.85 Mg/ha coconut garden over three year period) at the highest tree density of 49,382 plants/ha and at 12 weeks harvest interval, with proper nutrient management, and has fixed additional carbon of 33 Mg/ha over three year period in the plant biomass and in soil up to 40 cm depth, when compared to coconut monoculture systems. The B:C ratio over three year period was found to be 3.90 with annual net returns of 3 lakhs/ha. A field experiment was conducted at the centre to assess the understorey productivity of four fodder grasses *viz., Brachiaria ruziziensis Germain & Everard* (congosignal), *Panicum maximum Jacq.* (guinea), hybrid napier cultivar CO-3 and CO-5 under mature *coconut (Cocos nucifera L.) and rubber (Hevea brasiliensis Muell. Arg,) plantations.* The results indicated that the growth and yield attributes of fodder grasses under coconut plantation were almost comparable with open plots. Thus practice of integrating fodder grasses in coconut plantations can be taken up in a big way in a land crunch state like Kerala, where mature coconut plantations forms one of the extensive and prominent land management system.

Dapoli centre collected and conservated germplasm of *Garcinia indica*, *Tectona grandis*, *Bamboo species*, *Melia dubia*, *Mellittia pinnata* and *Acacia mangium*. *In Melia dubia* based medicinal agroforestry system, at the age of three years, the average height of *Melia dubia* was observed 11.82 m and CAI of height was 2.00 m, whereas dbh of *Melia dubia* was 17.55 cm and also CAI of dbh was 3.02 cm. Among the medicinal plant species, root weight per plant ranged from 4.86 g Adulsa (*Justicia adhatoda*) to 232 g *Gmelinia arborea*. Whereas, highest root length (69.8 cm) and stem weight (880.0 g) was observed in *Gmelinia arborea* per plant. The maximum branches weight per plant was recorded by Chitrak *(Plumbago zeylanica)* (110.17 g) followed by Tetu (*Oroxylum indicum*) (108.75 g). However highest leaves weight (88.25 g) was showed by the treatment Bel (*Aegle marmelos*) and lowest by Dorli (*Solanum khasianum*) (5.0 g). Highest total biomass given by Shivan (*Gmelinia arborea*) (1184.4 g) followed by Agnimonth (*Clerodendrum phlomidis*) (920 g). The centre recommended *that Acacia mangium*, *Gliricidia sepium*, *Pterocarpus marsupium* and *Acacia catechu* are to be planted as a source of nutrients in lateritic soils of Konkan region under agroforestry system for building up of soil fertility and carbon sequestration.

Under Evaluation, Selection and Establishment of clonal seed orchard of tamarind by Bangalore

centre, among 27 selections after eight years of planting NFN 1, NFN 2, NFN 3, NFN 7, NFN 8, NFN 9, NFN 10, PKM 11, H 2, H 12, SMG 14, GKVK 1, GKVK 2, GKVK 13, OORIGUM 1, DTS 2, Red tamarind and Sweet tamarind germplasms have started bearing. Higher cumulative yield of 24 kg/tree was recorded with NFN 9. NFN 9 fruits are long (19 cm), lower shell weight (1.94 g) and have higher pulp content (18 g). The performance of fourteen local selections, comprising of 7 each in 'Kaali' and 'Gouri' genotypes were found satisfactory under selection of elite trees and establishment of clonal seed orchard of *Simarouba glauca*.

In *Melia dubia* based agroforestry systems, after eight years of planting of *Melia dubia* the tree height was significantly higher in 24 x 5 m (13.34 m) followed by 20 x 5 m (13.19 m) and 16 x 5 m (12.72 m). Similar trend was observed with respect canopy spread in E-W (7.80, 7.53 & 7.19 m, respectively) and N-S (8.15, 7.99 and 7.71 m, respectively) direction. The nutrient status showed that, available nitrogen (298 kg/ha), phosphorus (29 kg/ha) and potassium (301kg/ha) were significantly higher under *Melia dubia* based agroforestry system over fallow land.

Five species of fodder trees *viz.*, *Sesbania grandiflora, Gliricidia sepium, Leucaena leucocephala, Calliandra calathyrus* and *Moringa olifera* are cultivated in paired row across the slope with a spacing of 0.5 m between trees 0.5 m between rows in zig zag planting. Among five tree species studied for leaf meal production, *Sesbania grandiflora* has recorded higher green biomass yield of 3.25 kg/tree/cutting followed by *Gliricidia sepium* 3.12 kg/tree/cutting. Alley spacing of 5 m were followed.

The Tribal sub Plan was implemented through participatory approach in Shettalli and Bhudipadaga villages of Mysore district, which covers 326 families. As a part of the programme forestry seedling *viz.,* Melia & silveroak and horticulture seedlings *viz.,* wood apple, custard apple, jack fruit and mango and agricultural implements *viz.*, sickle and gudli were supplied and trainings on improved cultivation practices on agriculture, horticulture and agroforestry system were organized. The agricultural crops such as maize, fingermillet, cotton etc., were cultivated. There was good crop during the year and released an average returns of ₹ 25,000/ha. It clearly showed that there was better impact of the programme on the improvement of their livelihood. STP famers of Sollepura village Smt. Daasi, Mr. Bhaskar and Mr. Basappa were awarded "Super Star Farmer" and issued Appreciation certificate by one of the lead newspapers of Karnataka Vijaya Karnataka. With the interventions of centre from 2012-13, STP farmers were able to cultivate agricultural and horticultural crops, planting of forest trees along the border. In last season they have taken up cultivation of vegetable crops and harvested an average yield of tomato (23 t/ha), brinjal (10 t/ha) and capsicum (5 t/ha) etc. With all these intervention it was possible to increase the annual income of the tribal farmer.

Total 105 candidate trees of silveroak were evaluated their phenotypic superiority and only 10 trees were categorised as Candidate Plus trees by Ponnampet centre. The centre conducted D & D exercise in Kodagu district and found that In the region, coffee plantations are the major agroforestry practices (41%) followed by scattered planting (18%), boundary planting (17%), home gardens (16%) and least was in bund planting (8%). Among the different agroforestry practices, coffee plantations had higher diversity of trees (Shanon diversity index: 2.032) followed by bund planting (0.226) and the least was noticed in boundary planting (0.078). Important tree species preferred for planting were *Acrocarpus fraxinifolius, Dalbergia latifolia, Ficus racemosa, Diospyros ebenum, Mangifera indica, Cinnamomum malabatrum, Artocarpus hirsutus* and *Myristica malabarica*.

Under teak based mixed agroforestry with suitable agronomic crops in semi-malenad areas, the teak height growth was significantly higher in the treatment having two rows of teak with *A. lebbeck* one row (4.92 m) which was on par with the treatments teak alone and two rows of teak with *C. junghuniana.* Centre initiated work on package and practices of Litsea species and thirty

month old *Litsea chinensis* trees were coppiced to get new flushes and softwood cuttings from the coppice shoots were used for rooting of cuttings.

Under the TSP programme tribal communities in the flood affected areas of Madikeri taluk and tribal families in Virajpet taluk were supported. Flood affected tribal families (40) in Madikeri taluk namely three villages (Mukkodlu, Haleri and Monnangeri) were provided with poultry birds to enhance their livelihood and nutritional security. Apart from these based on the preference 38 piglets were distributed tribals (38 families) to have their livelihood. Training programme on bee keeping was organised to seek livelihood option by the flood affected families. Majority of the tribal hamlets were not having electricity and students who were studying in the hamlets were provided solar lamps both in flood affected areas in Madikeri taluk and some places in Virajpet taluk.

CHAPTER

4 AWARDS AND RECOGNITIONS

- Dr. A K Handa, Pr. Scientist elected as one of the nine Founder Board Members of International Union of Agroforestry (IUAF) launched during 4th World Agroforestry Congress from 19th-22nd May, 2019 at Montpellier, France.
- Dr. Ramesh Singh along with Dr. Inder Dev, Dr. R K Tewari, Dr. S K Dhyani, Dr. O P Chaturvedi, Dr. R P Dwivedi, Dr. R H Rizvi, Dr. K B Sridhar, Sh. Rajendra Singh, Sh. Shishupal Singh and Dr. C K Bajpai received Nanaji Deshmukh ICAR Award for Outstanding Interdisciplinary Team Research in Agricultural and Allied Sciences 2018 for Natural Resource management and Agricultural Engineering. The award conferred on 16th July, 2019 at NASC, New Delhi on the occasion of 91st Foundation Day of Indian Council of Agricultural Research.

- Best research paper publication Award in 2019 by ICAR-CAFRI, Jhansi on its 31st Foundation Day for the research paper by Dr. Badre Alam, Rashmi Singh, Mayank Chaturvedi, Ram Newaj and O P Chaturvedi entitled "Determination of critical low light limit and adaptive physiological and biochemical traits regulating growth and yield of mustard (*Brassica juncea* Coss.). Published in *Physiology and Molecular Biology of Plants.* 24(5):985-992. https://doi.org./10.1007/s12298-018-0537-0"

- Dr. Asha Ram. Scientist awarded International Travel Support (ITS) grant from SERB, Department of Science & Technology, Government of India to attend 4th World Agroforestry Congress from 19th – 22nd May, 2019 at Montpellier, France.
- Sh. Lal Chand awarded with Best Worker (Field Operation) Award for scientific contribution for year 2018-19 by ICAR-CAFRI, Jhansi on its 31st Foundation Day (8th May, 2019).
- Sh. Lal Chand, Dr. Hirdayesh Anuragi, Dr. R K Tewari, Dr. Sudhir Kumar, Sh. Sukumar Tariya, Dr. Sangram Chavan, Dr. K Rajrajan, Dr. Asha Ram, Dr. Ramesh Singh and Dr. Inder dev won First prize in Poster competition in Hindi Saptah during 13th-19th September, 2019 on their poster entitled "Neembu Aadharit Krishivaniki".
- Dr. S B Chavan, Dr. Naresh Kumar, Dr. A K Handa and Dr. K B Shridhar won second prize in poster competition in Hindi Saptah during 13th-19th Sepetember on their poster entitled" Bundelkhand me Sagwan ki kheti: Doguni Aay ka Marg".
- Dr. Naresh Kumar, Dr. Anil Kumar, Dr. Sangram Chavan, Dr. K B Sridhar, Dr. A K Handa, Dr. R K Tiwari, Dr. Lal Chand, Dr. Mahendra Singh, Dr. R P Dwivedi, Sh. A R Uthappa and Sh. Dinesh Kumar Yadav won Third prize in Poster competition in Hindi

Saptah during 13th-19th September, 2019 on their poster entitled "Mahua: Bundelkhand me aajivika surakcha hetu ek vardan".

- Dr. Dhiraj Kumar Honored with Best Worker (Science & Institution Development) Award. This honor is conferred at the function of 31st Foundation Day Celebration on 8th May, 2019.
- Dr. Hirdayesh Anuragi, Scientist awarded with "Best Poster Presentation Award" on their Lavan Sahishnuta hetu Jai Ki Kismo Ka Roopatmak, Karyakiya Evem Jaiv Rasayanik Abhilakshan in Hindi Pakhwada-2019 organized by ICAR - Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi. This work was conducted by Dr. Hirdayesh Anuragi during his three month Professional Attachment Training (PA) at ICAR-IGFRI, Jhansi.

CHAPTER

5 VISIT ABROAD

- Dr. A K Handa, Pr. Scientist (Forestry/ Agroforestry) and Dr. Asha Ram, Scientist (Agronomy) participated in the 4th World Congress on "Agroforestry Strengthening links between science, society and policy" during 20th-22nd May, 2019 held at Montpellier, France.
- Dr. A K Handa, Pr. Scientist (Forestry/ Agroforestry) nominated by DARE as an Expert to assist Government of Republic of Djibouti for plantation drive under its Green Djibouti Plan from 15th – 21st October 2019 and presented a report for suitable tree species and action plan to green Djibouti
- Dr. A K Handa Pr. Scientist (Forestry/ Agroforestry) nominated by DARE to attend High Level Consultation on Agroforestry Policy for Vietnam held from 19th to 20th December, 2019 at Hanoi, Vietnam.

CHAPTER

6 ON GOING PROJECTS (2019-2020)

Sl.	Project Code	Title of the Project	Leader	Associates
(A)	**SYSTEM RESEARCH PROGRAMME**			
1	NRMACAFRISIL 201000200085	Nutrient management in ber based agri-horti. system	**Sudhir Kumar**	Rajendra Prasad, Inder Dev & Y N Venkatesh
2	NRMACAFRISIL 201600100099	Performance of pomegranate integrated with lemon grass under organic regime	**Sudhir Kumar**	Rajendra Prasad & Y N Venkatesh
3	NRMACAFRISIL 201600200100	Structural and functional analysis of short rotation tree based agroforestry system	**Naresh Kumar**	Asha Ram, Dhiraj Kumar, Inder Dev, Kamini (ICAR-IGFRI, Jhansi), Mahendra Singh* & S B Chavn
(B)	**NATURAL RESOURCE & ENVIRONMENT MANAGEMENT PROGRAMME**			
1	NRMACAFRISIL 201300100091	Agroforestry based conservation agriculture for sustainable landuse and improved productivity	**Inder Dev**	Asha Ram, Ramesh Singh, Dhiraj Kumar, K B Sridhar, Naresh Kumar, Lal Chand, Y N Venkatesh & Mahendra Singh*
2	NRMACAFRISIL 201600400102	Agroforestry based integrated farming system for small and marginal farmers in semi-arid region	**Ram Newaj**	Asha Ram, Sudhir Kumar, Naresh Kumar, Ramesh Singh, Dhiraj Kumar, R Vishnu, Y N Venkatesh & Mahendra Singh*
3	NRMACAFRISIL 201600500103	Impact of watershed and agroforestry interventions on hydrology and nutrient loss at Garhkundar-Dabar watershed in Bundelkhand region of Central India	**Ramesh Singh**	Dhiraj Kumar
4	NRMACAFRISIL 201600700104	Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions	**Asha Ram**	Ramesh Singh, Naresh Kumar, Inder Dev & Dhiraj Kumar

5	NRMACAFRISIL 201600700105	Horizontal and vertical distribution of fine roots of tree and nutrients content in well-established Aonla and *Hardwickia binata* based agroforestry system	**Dhiraj Kumar**	Ram Newaj, Rajendra Prasad & Asha Ram
6	NRMACAFRISIL 201900100117	Biomass modelling and area estimation in *Tectona grandis* based agroforestry systems in Central India	**S B Chavan**	R H Rizvi, Asha Ram & R Vishnu
(C)	**TREE IMPROVEMENT, POST-HARVEST & VALUE ADDITION PROGRAMME**			
1	NRMACAFRISIL 200700400071	Comparative studies on seedling and clonal plants of Pongamia pinnata with special reference to their adaptability to rainfed dry agroclimate	**Badre Alam**	A K Handa, Sukumar Taria, Hirdayesh Anuragi & Alka Bharti
2	NRMACAFRISIL 201500100092	Evaluation and characterisation of different Leucaena germplasm at CAFRI	**K Rajarajan**	A K Handa, A K Singh, (IGFRI), Maneet Rana (IGFRI) & S B Chavan
3	NRMACAFRISIL 201600900107	TBOs based agroforestry models	**K B Sridhar***	Inder Dev & R Vishnu
4	NRMACAFRISIL 201801100114	Functional genomics for early drought tolerance in *Pongamia pinnata* genotypes	**K Rajarajan**	K B Sridhar*, Lal Chand, A Radhakrishnan, Sukumar Taria, Hirdayesh Anuragi & Alka Bharti
5	NRMACAFRISIL 201900200118	Collection, evaluation and hybridization of Moringa germplasms	**Hirdayesh Anuragi**	Lal Chand, S B Chavan, Sukumar Taria, K Rajarajan, Alka Bharati & Y N Venkatesh
(D) HRD, TECHNOLOGY TRANSFER & REFINEMENT PROGRAMME				
1	NRMACAFRISIL 201500200093	Socio-economic, energetic and environmental impact assessment of watershed and agroforestry interventions at Garhkundar-Dabar watershed in Tikamgarh district of Madhya Pradesh	**R P Dwivedi**	R K Tewari, Ramesh Singh, R H Rizvi & Mahendra Singh*
Projects concluded during 2019				
1	NRMACAFRISIL 200800200078	Studies on arbuscular mycorrhizal fungi of important MPT's	**Anil Kumar**	Rajendra Prasad & Naresh Kumar

2	NRMACAFRISIL 201100200088	Multi-Source inventory methods for quantifying carbon stocks through generalized volume/ biomass equations for prominent agroforestry species in india	**R H Rizvi**	A K Handa
3	NRMACAFRISIL 2016001000108	Mass propagation of Industrial trees *viz. Eucalyptus tereticornis, Casuarina junghuhniana* Miq. *Melia dubia* and *Populus deltoides* using micro and mini clonal cuttings	**K B Sridhar**	Lal Chand
4	NRMACAFRISIL 201600300101	Studies on soil biodiversity & nutrient dynamics in different agroforestry & mono-cropping system	**Veeresh Kumar**	Anil Kumar, Dhiraj Kumar, Naresh Kumar, Mahendra Singh* & N Manjunath (IGFRI, Jhansi)
5	NRMACAFRISIL 201700200112	Integrated development of Jatropha and Karanj	**Lal Chand**	Naresh Kumar
6	NRMACAFRISIL 201601100110	Development of nursery of TBOs for quality planting material production	**K B Sridhar***	Naresh Kumar, Lal Chand & K Rajarajan
7	NRMACAFRISIL 201500300094	Economic evaluation of poplar and Eucalyptus based agroforestry systems prevalent in Indo-Gangetic Plains, India	**Mahendra Singh***	R P Dwivedi, Inder Dev, R H Rizvi, K B Sridhar & Dhiraj Kumar

EXTERNALLY FUNDED PROJECTS

Sl.	Project Code	Title of the Project	Leader	Associates	Funding Agency
1	NRMACAFRISOP 200800100075	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins	**Rajendra Prasad**	A K Handa, Ramesh Singh & Badre Alam	ICAR, IINR&G Ranchi
2	NRMACAFRISOL 201500700096	National Mission for Sustaining The Himalayan Ecosystems (NMSHE- Taskforce 6 for Himalayan Agriculture)	**A K Handa**	Inder Dev, Badre Alam, Mahendra Singh* & Asha Ram	DST, New Delhi
3	NRMACAFRISOL 20110030087	Assessment of carbon sequestration potential of agroforestry systems (NICRA)	**Ram Newaj**	Rajendra Prasad, A K Handa, Badre Alam, R H Rizvi & S B Chavan	ICAR Network Project

4	NRMACAFRISOL 201800100112	Mapping and estimation of area under Poplar based agroforestry systems in Indo- Gangetic Plains of India	**R H Rizvi**	A K Handa & K B Sridhar*	ICAR-ICRAF Work Plan
5	NRMACAFRISOL 201800200114	Transforming rural livelihood through agroforestry based natural resource management in drought prone Bundelkhand region, UP (Sub Project of KISAN MITrA project for doubling farmers' income in Bundelkhand region of Uttar Pradesh)	**Ramesh Singh**	Inder Dev R K Tewari Naresh Kumar Asha Ram Dhiraj Kumar & Lal Chand	ICRISAT, Hyderabad
6	NRMACAFRISOL 201800300115	Establishment of Hi-Tech nursery for the production of quality planting material	**Lal Chand**	Naresh Kumar K B Sridhar*	U P Agro-forestry Mission, Lucknow
7	NRMACAFRISOL 201800400116	Transforming rural livelihood and checking mitigation through agroforestry in conjunction with natural resource management in Bolangir and Nuapada districts of Odisha	**Ramesh Singh**	Inder Dev	ICAR-ICRAF Work Plan

INTER INSTITUTIONAL AND INTERNATIONAL COLLABORATIVE PROJECT

Sl.	Project Code	Title of the Project	Leader	Associates	Funding Agency
1	----	Water requirement of grass based intercropping system in semi-arid area	**J B Singh,** IGFRI, Jhansi	Ramesh Singh, Mahendra Prasad & Amit Kumar Singh	Inter-Insti-tutional (IGFRI-Jhansi)
2	NRMACAFRISOP 201100100085	Enhancing groundwater recharge and water use efficiency in SAT Region through watershed interventions-Parasai-Sindh Watershed, Jhansi	**Ramesh Singh**	R K Tewari, Inder Dev, R H Rizvi , R P Dwivedi, K B Sridhar*, Dhiraj Kumar & Mahender Singh*	ICRISAT, Hyderabad
3	----	Farmer FIRST programme (FFP): Scaling up and integration of fodder technologies in existing farming system for sustainable livestock productivity in Bundelkhand	**Purshottam Sharma**	Sunil Seth, S K Mahanta, Harsh Vardhan Singh, Mukesh Choudhary & R P Dwivedi	Inter-Insti-tutional (IGFRI-Jhansi)

• Associated upto 30th November, 2019

CHAPTER

7 IMPORTANT MEETINGS /ACTIVITIES

National Productivity Week

ICAR-CAFRI organized National Productivity Week during 12th -18th February, 2019. On the occasion Dr. Mahendra Singh, Pr. Scientist (Agril. Econ.) highlighted need for circular economy for enhancing the productivity and sustainability. Dr. Rajendra Prasad, Pr. Scientist (Soil Sci.) deliberated on recycling of materials for input cost reduction and environment protection in agriculture sector for benefit of future generation. Dr. Naresh Kumar, Sr. Sci. (Forestry) highlighted vision of Mahatma Gandhi which formed basis for orienting economic development strategy to focus on circular economy. The function was attended by all staff members.

International Women's Day

The event was organized on 8th March, 2019 at the Institute. On the occasion Hon'ble PM's address was telecasted. Staff of the Institute participated in the discussion on the theme "Think equal, build smart and innovate for change". Mrs. Shelja Tamrakar and Mrs. Kaushalya Devi expressed their views on gender issues and general atmosphere in offices and society regarding working women. Every one realized that there is sufficient change in mind set of both men and women yet lot more change is desirable to encourage women in different walks of life. It was unanimously agreed that women power will add to prosperity and progress of society in general and country as a whole. The programme was attended by all staff members and workers.

Research Advisory Committee

21st RAC meeting of ICAR-CAFRI was held during 12th-13th March, 2019 under the chairmanship of Dr. K Gurumurthi, Ex. Director, IFGTB, Coimbatore; Dr. S Bhaskar, ADG (Agron./AF & CC), NRM Division, ICAR, New Delhi; Dr. S K Dhyani, Senior Agroforestry Expert, World Agroforestry (ICRAF), New Delhi; Dr. S D Bhardwaj, Formar Dean, Y S P University of Horti. & Forestry, Solan; Dr. A K Mandal, Former Director, TFRI, Jabalpur; Dr. B N Patel, Principal and Dean, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari; Dr. R C Dhiman, Former General Manager, WIMCO Seedling Limited, R&D Centre, Bagwala, Kashipur Road, Rudrapur; Sh. Ashok Kumar Rajput, Dr. Anil Kumar, Director (A), ICAR-CAFRI, Jhansi and Dr. Inder Dev, Pr. Scientist & Member secretary RAC participated in the meeting. The Committee interacted with the Scientists and reviewed the ATR of previous RAC. The RAC also visited the Agroforestry based Parasai - Sindh Watershed developed by the Institute.

31st Foundation Day

ICAR-CAFRI, Jhansi celebrated its 31st Foundation Day on 8th May, 2019. Dr. S Bhaskar, ADG (Agron./AF & CC), NRM Division, ICAR, New Delhi was the Chief Guest of the function.

Dr. Shiv Kumar Dhyani, Sr. Agroforestry Specialist, ICRAF, New Delhi, Dr. Sreenath Dixit, Theme Leader, ICRISAT Development Center (IDC), ICRISAT, Patancheru and Dr. A K Mishra, Director, ICAR-IGFRI, Jhansi were the special guests of the function. They appreciated the contributions made by the ICAR-CAFRI, Jhansi. During the function 09 number of publications were released by the chief guest.

International Yoga Day

International Yoga Day was organized on 21st June, 2019 at the Institute. On the eve of Yoga Day Scientific, administrative, technical and supporting staff participated in the different activities.

Institute Research Council

Institute Research Council (IRC) meeting was held on 4th, 5th July, 2019 and 2nd September, 2019. All the Scientists of the Institute participated in the meeting and presented the progress and significant findings of their projects.

हिन्दी सप्ताह

दिनांक 13.09.2019 को हिन्दी सप्ताह का उद्घाटन सत्र संस्थान के निदेशक (कार्यवाहक) डा. अनिल कुमार की अध्यक्षता में प्रारंम्भ हुआ। कार्यक्रम का प्रारम्भ आई.सी.ए.आर कुलगीत से किया गया। उसके उपरान्त डॉ. इन्द्र देव, प्रधान वैज्ञानिक द्वारा मान्नीय कृषि मंत्री, भारत सरकार का हिन्दी दिवस पर संदेश तथा श्री बी. सिंह, मुख्य प्रक्षेत्र प्रबन्धक द्वारा भारतीय कृषि अनुंसधान परिषद के महानिदेशक महोदय की अपील पढ़कर सभी को उनके बहुमूल्य विचारों से अवगत कराया।

दिनांक 19.09.2019 को हिन्दी सप्ताह के समापन कार्यक्रम की अध्यक्षता करते हुए संस्थान के कार्यवाहक निदेशक डा.

आर.के. तिवारी ने अपने उद्बोधन में कहा कि शोध कार्यों में विशेषकर प्रकाशन, संदर्भ–संग्रह, कृषि उपयोगी जानकारी इत्यादि में हिन्दी के प्रयोग को बढ़ाये जाने की आवश्यकता है। उन्होने कहा कि विश्व में कई ऐसे देश हैं जो कि अपने अनुसंधान कार्य के लिए राष्ट्रभाषा का प्रयोग करते हैं, इसी कारण दूसरे देशों में विज्ञान एवं अनुसंधान जन–जन तक राष्ट्रभाषा के माध्यम से पहुँचा है। हमारे देश भारत में हिन्दी को राजभाशा से राष्ट्रभाषा करने हेतु प्रयास की जरूरत है तभी आम आदमी को विज्ञान एवं अनुसंधान कार्य हिन्दी में समझने में आसानी होगी। उन्होंने राजभाषा अधिनियम 1963 की धारा 3 (3) एवं राजभाषा नियमों, 1976 का उल्लेख करते हुए सभी से अपने दैनिक कार्यों में इसके अनुपालन करने की अपील की। कार्यक्रम की अध्यक्षता करते हुए निदेशक महोदय ने पुरस्कृत प्रतिभागियों को बधाई देते हुए वैज्ञानिकों से अपील की कि वे संस्थान में विकसित तकनीकियों को किसानों तक हिन्दी भाषा में पहुँचाने हेतु और अधिक प्रयास करें।

Workshop on Uttar Pradesh Tree Protection Act, 1976 and Agroforestry Mission

The one day workshop on "Uttar Pradesh Tree Protection Act, 1976 and Agroforestry Mission" was organised by Department of Environment, Forest and Climate Change of Uttar Pradesh

with collaboration of ICAR-CAFRI, Jhansi on 18th September, 2019 at ICAR-Indian Grassland and Fodder Research Institute, Jhansi. The programme was chaired by Sh. Pawan Kumar, PCCF & HOFF, Dr. R K Tiwari, Director ICAR-CAFRI, Jhansi, Dr. A K Roy, Director, IGFRI, Jhansi. Forest officials, Scientist of ICAR-CAFRI & IGFRI, Jhansi and Farmers of nine agroclimatic zones of Uttar Pradesh participated in the training programme.

QRT Meeting

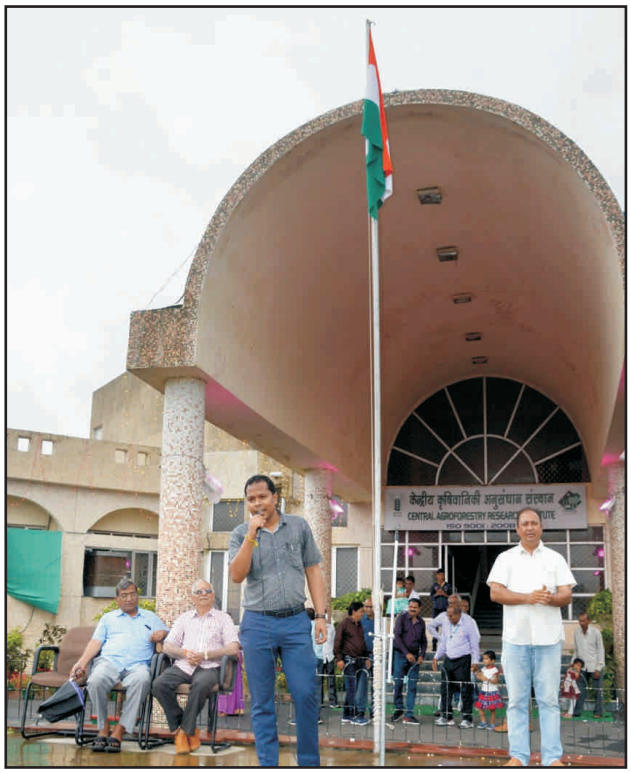
Under the Chairmanship of Dr. K R Dhiman, Former Vice Chancellor, Dr. YSPUH & FS, Solan (H.P.) 5th QRT meeting was held on 11th -12th December, 2019 at the Institute. Dr. A K Vasisht, Former ADG (PIM), ICAR, New Delhi, Dr. Rajeshwar Chandel, Executive Director, Natural Farming, Department of Agriculture, Shimla (H.P.), Dr. A K Mohpatra, Former Professor Agronomy, OUAT, Bhubneshwar (Odisha) and Dr. S J Patil, Professor & Head, Department of Silviculture and Agroforestry & Dean, Student Welfare Officer, UAS, Dharwad (K.A.) Members of QRT participated in the meeting. Dr. Anil Kumar, Director (A), ICAR-CAFRI, Jhansi and Dr. A K Handa, Pr. Scientist & Member Secretary of QRT participated in the QRT meeting. The Committee interacted with the Scientists as well all the staff of the Institute and reviewed the ATR of previous QRT. The QRT team also visited Research Farm of the ICAR-CAFRI and the Agroforestry based Lalitpur Watershed developed by the Institute.

World Soil Day

ICAR - Central Agroforestry Research Institute, Jhansi organized the World Soil Day on 05th December, 2019. The programme was presided over by Dr. R K Tewari, Director (A), ICAR-CAFRI, Jhansi. At the outset, Dr. Dhiraj Kumar, Scientist (Soil Science) highlighted about the idea behind celebration of World Soil Day and its importance. Dr. Ramesh Singh, Principal Scientist (Soil and Water Conservation Engineering) talked in brief about different aspects of soil erosion and how through agroforestry measures, it can be stopped by it by maintaining the whole ecosystem services as this year the theme of world soil day was "Stop Soil Erosion, Save Our Future". Dr. Rajendra Prasad, Principal Scientist (Soil Science) talked about different aspects of soil degradation and how it started in our country, the manner in which multi-nutrient deficiencies have been spread across the country and its implications at different scales. The idea of soil health card distribution and how through soil test based fertilizers recommendation, the farmers were given package of practice for obtaining potential yield. Director of the Institute, highlighted about the institute and its mandate, through which we are involved in saving our soils against various forms of degradation by integration of trees along with crops, thus having a whole array of ecosystem benefits. He emphasized how the Institute is involved in different programmes and up scaling work in farmer's field for fulfilling the objective of soil conservation and environmental security.

Republic Day and Independence Day

Republic Day (26th January, 2019) and Independence Day (15th August, 2019) were celebrated at ICAR-CAFRI, Jhansi. Flag hoisting ceremony was observed on both the occasions. Cultural programmes and sport events were organized for the staff along with their family members on the occasions.



CHAPTER

8 PARTICIPATION IN WORKSHOP/ COORDINATION/MEETINGS/SYMPOSIA

Duration	Event	Venue	Participants
16th January, 2019	Co-Chaired one Session in Biennial workshop of AICRP on DA	UAS, Bengaluru (KA)	Dr. A K Handa
24th - 25th January, 2019	Review meeting of ICAR-CGIAR	NASC Complex, New Delhi	Dr. A K Handa
28th January, 2019	XXXIXth PGRC meeting	ICAR-NBPGR, New Delhi	Dr. K Rajarajan
4th - 5th February, 2019	XXV meeting of Regional committee VI of ICAR	AAU, Anand (Gujarat)	Dr A K Handa
11th - 14th February, 2019	13th International Conference on "Development of drylands converting dryland areas from grey into green"	Jodhpur, India	Dr. Dhiraj Kumar
18th February, 2019	Second meeting of state level standing technical committee for UP agroforestry mission	Lucknow (U.P.)	Dr. A K Handa
18th - 20th February, 2019	International Workshop on "Earth Observations for Agricultural Monitoring" jointly organized by ISPRS & ISRS	IARI, New Delhi	Dr. R H Rizvi
20th - 23rd February, 2019	XIV Agricultural Science Congress	NASC Complex, New Delhi	Dr. Rajendra Prasad, Dr. Sudhir Kumar, Dr. Mahendra Singh & Dr. K Rajarajan
6th March, 2019	National Consultation on Application of IT in Agricultural Research	NASC, New Delhi	Dr. R H Rizvi
3rd June, 2019	Co-Chaired one technical session in Regional Research Conference of ICFRE for North region	Lucknow (U P)	Dr. A K Handa
7th June, 2019	Student Agricultural Research Conference (As Expert Member)	RSKV, Gwalior (M P)	Dr. A K Handa

17th June, 2019	One day workshop on "World Day to Combat Desertification and Drought"	ICAR-CAFRI, Jhansi in collaboration with ICAR-CAFRI, Jhansi; ICAR; IGFRI, Jhansi; ICRISAT, Hyderabad and UP Forest Department	All Pr. Scientists, Sr. Scientists and Scientists
12th July, 2019	State Level Review meeting of ICAR Regional Committee No 1	SKUAST, Jammu (J&K)	Dr. A K Handa
25th - 26th July, 2019	Annual Review Meeting of National Innovations in Climate Resilient Agriculture	NASC Complex, New Delhi	Dr. S B Chavan & Dr. Dhiraj Kumar
27th - 29th July, 2019	Workshop on KVKs of ICAR-ARARI Jabalpur Zone	Khajuraho, (Chhatarpur) (M P)	Dr. R P Dwivedi
9th -10th August, 2019	XXV Meeting of Regional Committee	Nagpur	Dr. A K Handa
16th August, 2019	Meeting of the committee to include ToF as item for assistance under State Disaster Response Fund and National Disaster Response Fund	NRAA, New Delhi	Dr. A K Handa
12th September, 2019	Review Meeting of Establishment of Hi Tech Nursery for the Production of Quality Planting Material (U.P. Agroforestry Mission)	U.P. Agroforestry Mission, Lucknow (U P)	Sh. Lal Chand, Dr. K B Sridhar & Sh. R Vishnu
18th - 20th September, 2019	Workshop of AICRP on Agroforestry	FCRI, Mettupalaym (TN)	Dr. Anil Kumar & Dr. A K Handa
25th September, 2019	Brain Storming session on Tree Genomics Organized by NRM Division, ICAR in collaboration with World Agroforestry Centre, New Delhi	NASC Complex, New Delhi	Dr. A K Handa, Dr. S B Chavan, Dr. K Rajarajan, Dr. Hirdayesh Anuragi & Mrs. Alka Bharati
31st October, 2019	Brainstorming Workshop on Payment for Ecosystem Services in Agriculture organized by NAAS	NASC Complex, New Delhi	Dr. Badre Alam
31st October - 01st November, 2019	Training cum Workshop for Vigilance Officers of ICAR	ICAR-NAARM, Hyderabad (Telangana)	Dr. Sudhir Kumar

14th - 16th November, 2019	National seminar on Holistic approaches for enhancing agricultural growth in changing rural scenario organized by ISEE (IARI) , New Delhi	SKRAU, Bikaner (Rajasthan)	Dr. R P Dwivedi
19th - 20th November, 2019	11th Annual workshop of HPVA NRG Project	Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani (Maharashtra)	Dr. Rajendra Prasad
25th November, 2019	Draft EFC meeting of NRM Division	ICAR, New Delhi	Dr. A K Handa
4th December, 2019	Delivered an invited lecture in Short course on Agroforestry	KAU, Thrissur (KA)	Dr. A K Handa
10th - 11th December, 2019	4th National workshop of Nodal Officer In-charge, Data management (ICAR Research Data Repository for Knowledge Management)"	ICAR - Indian Agricultural Statistics Research Institute at NASC Complex, New Delhi	Dr. Hirdayesh Anuragi
16th - 17th December, 2019	Review Workshop of DFI project	ICRISAT, Hyderabad (Telangana)	Dr. R K Tewari, Dr. Ramesh Singh & Dr. Inder Dev
17th -18th December, 2019	7th NICRA Annual Review Workshop	NASC complex, New Delhi	Dr. Badre Alam & Dr. S B Chawan
19th - 21st December, 2019	National Conference of Plant Physiology	Thrissur (Kerala)	Mr. Sukumar Taria

CHAPTER 9 PUBLICATIONS

(A) Research Journals

Chand L, Singh, D B, Kumawat, K L, Rai, K M, Sharma, O C, Sharma, A, Saini, P, Handa, A K (2020). Genetic variability, correlation and path-coefficient studies for nut and kernel traits among the Persian walnut (*Juglans regia* L.) genotypes. *Indian Journal of Agricultural Sciences,* Accepted: 08 September 2019.

Chavan, S B and Dhillon, R S (2019). Doubling farmers' income through *Populus deltoides* based agroforestry systems in North-Western India: An economic analysis. *Current Science*, 117(2): 219-226.

Chhavi, Sirohi, Bangarwa, K S, Dhillon, R S, Chavan, S B and Ahlawat, K S (2019). Agroforestry: A multifunctional system for livelihood and environmental security. *Indian Farming*, 69(08): 30–31.

Kumar, Naresh, Kamini, Asha Ram, Handa, Arun Kumar, Dev, Inder, Lal Chand, Shukla, Ashok and Kumar, Dhiraj (2019) Allelopathic impact of *Anthocephalus cadamba* (Roxb.) Miq. and *Melia dubia* Cav. on *Triticum aestivum* L.: Bioassay study. *Journal of Pharmacognosy and Phytochemistry,* 8(1): 1265-1269.

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कुमार, नरेश, चव्हाण, संग्राम, श्रीधर, के. बी., हाण्डा, ऐ. के., तिवारी, आर. के., चन्द, लाल, सिंह, महेन्द्र, द्विवेदी, आर. पी., सिंह, रमेश, उथप्पा,ए. आर. एवं यादव, दिनेश कुमार (2019)। महुआः बुन्देलखण्ड में आजीविका सुरक्षा हेतु एक वरदान. प्रसार पत्रक–02/2019। भा.कृ.अनु.प. –केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी (उत्तर प्रदेश)।

चव्हाण, संग्राम, नेवाज, राम, अनुरागी, हृदयेश, राजराजन, के., चन्द, लाल, कुमार, धीरज, राम, आशा, देव, इन्द्र एवं राजावत, ब्रजपाल (2019)। सहजन आधारित कृषिवानिकी : उत्पादन पद्धतियाँ। प्रसार पत्रक–03/2019। भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी (उत्तर प्रदेश)।

प्रसाद, राजेन्द्र, सिंह, रमेश, हाण्डा, ए.के., आलम, बद्रे, शुक्ला, अशोक, सिंह, प्रशांत, सिंह, आनंद कुमार, तिवारी, आर. के. एवं कुमार, सुधीर (2019)। खेतों की मेड़ पर कुमट (गम अरेबिक) की सजीव बाड़ लगाएँ गोंद से आय एवं अन्ना–पशुओं से फसल सुरक्षा पाएँ। प्रसार पत्रक–04/2019। भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी (उत्तर प्रदेश)।

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चन्द, लाल, तारिया, सुकुमार, तिवारी, आर.के., कुमार, सुधीर, अनुरागी, हृदयेश, चव्हाण, संग्राम, कुमार, नरेश, सिंह, रमेश, देव, इन्द्र एवं हान्डा, ए.के. (2019)। अमरुद आधारित कृषिवानिकी : स्थापन एवं प्रबन्धन। प्रसार पत्रक–06/2019। भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी (उत्तर प्रदेश)।

चन्द, लाल, अनुरागी, हृदयेश, तिवारी, आर.के., कुमार, सुधीर, तारिया, सुकुमार, राजराजन, के., राम, आशा, सिंह, रमेश, देव, इन्द्र एवं हान्डा, ए.के. (2019)। नींबू आधारित कृषिवानिकी। प्रसार पत्रक–07/2019। भा.कृ.अनु.प. –केन्द्रीय कृषिवानिकी अनुसंधान संस्थान, झाँसी (उत्तर प्रदेश)।

CHAPTER

10 TRAINING AND CAPACITY BUILDING

A. Participation in Trainings

Duration	Event	Venue	Participants
16th November 2018-14th February, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services	ICAR- National Institute of Abiotic Stress Management, Baramati, Pune (MH)	Mr. Sukumar Taria
14th November 2018-14th February, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services	ICAR- Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, UP	Mr. Hirdayesh Anuragi
16th May-16th August, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services	ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru	Mr. Y N Venkatesh
16th May-16th August, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services	ICAR-National Institute for Plant Biotechnology, New Delhi	Mrs. Alka Bharati
16th May to 16th August, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services	Kerala Forest Research Institute, Thrissur, Kerala	Sh. R Vishnu
18th-23rd July, 2019	MDP on PME	NAARM, Hyderabad	Dr. Inder Dev
31st October-1st November, 2019	Training/Workshop for Vigilance Officers of ICAR	ICAR-NAARM, Hyderabad	Dr Sudhir Kumar

B. Trainings organized for Various Categories of Employees

Event	Duration	Venue	Participants
Training cum Exposure visit of ICRAF-Odisha stakeholders for Agroforestry & NRM activities	27th -31st May, 2019	ICAR-CAFRI, Jhansi	Odisha stakeholders
Training of ICRAF-Odisha farmers and ICRAF Odisha project staff	20th-24th September, 2019	ICAR-CAFRI, Jhansi	Eleven farmers and 02 project staff
International Training Programme on "Agroforestry" for Middle level Policy Makers from Asian and African countries. The Training was jointly organized by National Institute of Agricultural Extension Management (MANAGE) in collaboration with Indian Council of Agriculture Research (ICAR); ICAR-Central Agroforestry Research Institute, Jhansi; Forest College & Research Institute, Mettupalayam, Tamil Nadu; and World Agroforestry (International Centre for Agroforestry Research-ICRAF)	10th- 24th October, 2019	ICAR-CAFRI, Jhansi	Twenty Six participants from Sri Lanka (5), Bangladesh (2), Botswana (1), Cambodia (1), Kenya (1), Malawi (2), Nepal (7), Myanmar (4), Tanzania (1) and Uganda (2)
Exposure visit of Gardner (Mali) from Horticultural Experiment and Training Center, Baruasagar, Jhansi	23rd October, 2019	ICAR-CAFRI, Jhansi	Fifty Gardner (Mali)
Training cum Exposure visit of ICRAF-Odisha stakeholders for Agroforestry & NRM activities	11th-15th, November, 2019	ICAR-CAFRI, Jhansi	Eight Officials from Odisha and ICRAF, New Delhi

C. HRD funds Allocation and Utilization

(₹ in Lakh)

Year	Allocation	Utilization
2019-2020	0.34	0.34

CHAPTER

11 SWACHH BHARAT ABHIYAN

स्वच्छता ही सेवा'' कार्यक्रम

"स्वच्छता ही सेवा" अभियान–2019 का आयोजन दिनाँक 11.09.2019 को भाकृअनुप–केन्द्रीय कृशिवानिकी अनुसंधान संस्थान, झाँसी में किया गया। ''स्वच्छता ही सेवा'' अभियान–2019 का प्रमुख उद्देश्य देश में स्वच्छता के प्रति जागरूकता फैलाना है।इस कार्यक्रम के अन्तर्गत दिनाँक 20 सितम्बर, 2019 को भोजला तथा दिनाँक 25 सितम्बर, 2019 को प्राथमिक तथा उच्च प्राथमिक विद्यालय, ग्राम सिमरधा में ''प्लास्टिक कचरा प्रबन्धन'' पर जागरूकता कार्यक्रम आयोजन किया गया। कार्यक्रम के दौरान बैनर का प्रदर्शन किया गया और बच्चों को स्वच्छता की शपथ दिलाई गयी।

Swachhta Pakhwada

The Swachhta Pakhwada was organized by the ICAR- CAFRI, Jhansi from 16th to 31st December, 2019as per the date wise action plan. Scientific, administrative and technical staff along with the Research associates, SRFs actively participated in the programme.

A programme was initiated with taking Swachhta pledge on 16/12/2019. Scientist briefed the audience about the importance of cleanliness in the life and activities to be organized during the Swachhta Pakhwada.

On 17/12/2019 Scientist and team briefed the participants about importance of stock taking on digitalization of office records/ e- office implementation, cleanliness in the office, corridors and premises as well as weeding out old records, disposing of old and obsolete furniture's, junk materials etc.

The Swachhta Pakhwada was organized in the village 'Simardha' adopted under 'Mera Gaon Mera Gaurav' programme of Govt. of India on 18/12/2019. Scientists addressed the villagers and school going kids about the importance of sanitation and Solid Waste Management in day to day life. They were taught and encouraged to

start sanitation and hygienic living from their home itself and to discuss with their family members about maintaining cleanliness in and around the house.

Staff visited the colony area on 19/12/2019 and picked plastic waste and collected at a single place in order to develop wealth from waste in forthcoming events of Swachhta Pakhwada and discussed various strategies for sanitation and plastic waste management right from their homes within the campus and surroundings including residential colonies. Encouraged people to maintain cleanliness in and around their colonies and requested them to extend the message to their neighbors and local villagers.

Director and Scientistaddressed the gathering about generating wealth from home or kitchen garden based organic and plastic waste in order to maintain the cleanliness in and around the campus on 20/12/2019. Generating organic manure from vegetable waste and animal/bird scarer from polythene waste could be one of the simple and best strategies for the farming community. Staff visited the colony area and picked plastic waste and tied them on the fences which will scare birds and animals by creating sounds when wind comes. All have discussed various strategies for generating manures from vegetable based organic wastes coming out of the home and encouraged people to avoid the use of Single Use Plastics (SUPs) and maintain cleanliness in and around their colonies.

Director and Scientist addressed the gathering about waste water management on 21/12/2019. A visit was made with a campaign for cleaning the sewerage and water lines, spreading awareness on recycling of waste water, rain water harvesting for agriculture and horticulture applications, kitchen garden in residential colonies. Various strategies for rain water harvesting, storing and utilizing for various domestic and agricultural or horticultural purposes. Waste water coming out of the houses could be efficiently utilized for maintaining kitchen garden.

Farmers and villagers from nearby village were invited and demonstrated a technology for converting waste in to wealth on 22/12/2019. Director and Scientist addressed the gathering and explained in detail about generating manures from farm and kitchen waste which can be efficiently utilized in agriculture/horticulture and kitchen garden. This will not only reduce the pollution from organic waste, but also provide the source of low cost, high quality organic manure. Encouraged the farmers to avoid the use of Single Use Plastics (SUPs) and safely dispose the biodegradable waste coming out of the farm and houses.

On 23/12/2019 in the village 'Rajapur'(a village adopted under Doubling Farmers Income project of GOI) with the aim of celebrating a special day- KISAN DIWAS (FARMER'S DAY) by participating villagers and farmers.Director and Scientists delivered inspiring lectures on importance of farming and farmers in the country. They also discussed on crop diversification and encouraged the villagers to adopt integrated farming system which involves crops, trees, livestocks, poultries, fisheries etc. The villagers were encouraged to maintain the cleanliness in and around their village and avoid the usage of Single-Use Plastics in day to day life. The importance of education to their kids and living healthy life by adopting diversified food pattern was also explained to them. Distributed few basic farming tools and equipments like sickle, spade, pickaxe, plastic basket, knapsack prayer etc. to the farmers/villagers belonging to the financially weaker sections in order to encourage them for farming.

The Karari villagers were encouraged to maintain the cleanliness in and around their village and minimize the usage of Single-Use Plastics in day to day life on 24/12/2019. They were also taught to educate their families for living a healthy life by following some fundamental principles on daily basis.

All the staff members visited near Pahuj Dam on 25/12/2019 and performed the cleaning activities near the dam and collected plastic bottles, paper wastes, disposals etc. which were about to enter in to the dam and disposed at a safer place. Encouraged the visitors to avoid throwing disposable plastics or any other waste on the roadside or any public places and contribute in maintaining the clean and healthy environment.

Director addressed the students on 26/12/2019 and emphasized on importance of cleanliness in surrounding area of Primary school, Budha Nagar, Jhansi. Scientist highlighted importance of sanitation and the ongoing cleanliness drive "Swachha Bharat" started by our respected Prime Minister, Shri Narendra Modi. A quiz competition on Swachchhta Pakhwada was organized amongst the students. The campaign reaffirmed and reinstated the importance of

healthy surroundings and motivated all the students to work for making "India" a "Clean India".

Technologies for waste management including the importance of polythene free status were discussed on 27/12/2019. Accordingly non-degradable wastes were disposed off in an appropriate manner and degradable wastes were put in compost pit for recycling. Then discussed about the various process of composting of Kitchen Waste into a form that can be used as natural fertilizer forplants.

All the staff members discussed about the importance of cleaning of sewerage and water line in their locality Karari village on 28/12/2019.Director deliberated about the contaminated water which causes many water-borne infections like diarrhoea and also serves as a carrier for vectors such as mosquitoes spreading epidemics. Then we discussed about the importance of kitchen garden to ensure an inexpensive, regular and handy supply of fresh vegetables to their families which are basic tonutrition.

Staff members visited on 29/12/2019 at waste disposal sites of Karari village involving local people of. Director of the ICAR-CAFRI, Jhansi discussed about the NADEP method of composting which is the best way to make compost. Then we discussed about the safe disposal of bio-degradable/non-biodegradable waste. Accordingly degradable wastes were disposed off in an appropriate manner for composting.

On 30/12/2019 staff members discussed about the most significant cleanliness campaign being run by the Government of India. People from different sections of Simardha village have come forward and joined this mass movement of cleanliness and interact with villagers personally for creating awareness.

A meeting was organized on 31/12/2019 for reviewing the activities of Swachh Bharat Pakhwada 2019 conducted during last fifteen days (16.12.2019- 31.12.2019). Farmers/villagers have shared their opinion on Swachhta campaign. Finally we concluded the program with a promise to make India as "cleanIndia".


स्वच्छता पखवाड़ा

CHAPTER

12 DISTINGUISHED VISITORS

- Hon'ble Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi visited the Institute on 26th October, 2019.
- Dr. S Bhaskar, ADG (Agron./AF & CC), NRM Division, ICAR, New Delhi.
- Dr. Shiv Kumar Dhyani, Sr. Agroforestry Specialist, ICRAF, New Delhi.
- Dr. K Gurumurthi, Former Director, IFGTB, Coimbatore (T .N.).
- Dr. K R Dhiman, Former Vice Chancellor, Dr. Yashwant Singh Parmar University of Horticulture and Forestry (YSPUH & FS), Solan (H.P.).
- Dr. A K Vasisht, Former ADG (PIM), Indian Council of Agricultural Research (ICAR), New Delhi.
- Dr. Rajeshwar Chandel, Executive Director, Natural Farming, Department of Agriculture, Shimla (H.P.).
- Dr. A K Mohpatra, Former Professor Agronomy, Odisha University of Agriculture and Technology (OUAT), Bhubaneshwar (Odisha).
- Dr. S J Patil, Professor & Head, Department of Silviculture and Agroforestry & Dean, Student Welfare Officer, University of Agricultural Sciences (UAS), Dharwad (K.A.).
- Dr. R C Dhiman, Former General Manager, WIMCO Seedling Limited, R & D Centre, Bagwala, Kashipur Road, Rudrapur (Uttrakhand).

- Dr. S D Bhardwaj, Former Dean, Dr. Y.S.P. University of Horti. & Forestry, Solan (H.P.)
- Dr. A K Mandal, Former Director, TFRI, Jabalpur (M P).
- Dr. B N Patel, Principal and Dean, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (G.A.).
- Dr. Sreenath Dixit, Theme Leader, ICRISAT Development Center (IDC), ICRISAT, Patancheru (Telangana).
- Sh. Pawan Kumar, PCCF & HOFF, Government of Uttar Pradesh, Lucknow (U.P.).
- Dr. A K Mishra, Director, ICAR-IGFRI, Jhansi (UP).
- Sh. Ashok Kumar Rajput, Village- Nandsiya, Mooth, Post- Karjanva, Jhansi (U.P.).

CHAPTER 13 PERSONNEL

Dr. Anil Kumar, Director (A), up to 31st December, 2019	
Dr. R K Tewari, Director (A), w.e.f. 1st January, 2020	
Scientific	
1. Dr. Ram Newaj	Pr. Scientist (Agronomy)
2. Dr. Rajendra Prasad	Pr. Scientist (Soil Science)
3. Dr. Sudhir Kumar	Pr. Scientist (Horticulture/ Fruit Science)
4. Dr. A K Handa	Pr. Scientist (Forestry/ Agroforestry)
5. Dr. R P Dwivedi	Pr. Scientist (Agriculture Extension)
6. Dr. Inder Dev	Pr. Scientist (Agronomy)
7. Dr. Badre Alam	Pr. Scientist (Plant Physiology)
8. Dr. (Er.) Ramesh Singh	Pr. Scientist (SWC Engs.)
9. Dr. R H Rizvi	Pr. Scientist (Computer Application)
10. Dr. Naresh Kumar	Sr. Scientist (Agroforestry)
11. Dr. K Rajarajan	Scientist (Genetics & Plant Breeding)
12. Dr. Sushil Kumar	Scientist (Agronomy)
13. Dr. S B Chavan	Scientist (Forestry)
14. Dr. Asha Ram	Scientist (Agronomy)
15. Sh. A R Uthappa	Scientist (Forestry) (on Study Leave)
16. Dr. Dhiraj Kumar	Scientist (Soil Science)
17. Sh. Lal Chand	Scientist (Fruit Science)
18. Sh. Hirdayesh Anuragi	Scientist (Genetics & Plant Breeding)
19. Sh. Sukumar Taria	Scientist (Plant Physiology)
20. Sh. R Vishnu	Scientist (Agroforestry)
21. Mrs. Alka Bharti	Scientist (Agril. Biotechnology)
22. Sh. Y N Venkatesh	Scientist (Agril. Entomology)
Technical	
1. Dr. Rajeev Tiwari	Chief Technical Officer
2. Dr. C K Bajpai	Chief Technical Officer
3. Dr. A Datta	Chief Technical Officer
4. Sh. Sunil Kumar	Chief Technical Officer

5. Sh. Rajendra Singh	Chief Technical Officer
6. Sh. Rajesh Srivastava	Assit. Chief Technical Officer (Art & Photo)
7. Sh. R K Singh	Assit. Chief Technical Officer
8. Sh. S P Singh	Sr. Technical Officer
9. Sh. Ram Bahadur	Sr. Technical Officer
10. Sh. Ajay Kumar Pandey	Technical Officer (on Study Leave)
11. Mrs. Shelja Tamrkar	Sr. Technical Assistant (Library)
12. Sh. Het Ram	Sr. Technical Assistant (Driver)
13. Sh. Kashi Ram	Sr. Technical Assistant (Driver)
14. Sh. Prince	Technical Assistant, Mechanic
Administration	
1. Sh. J L Sharma	A O
2. Sh. Birendra Singh	AAO
3. Sh. S B Sharma	A F & A O
4. Sh. A K Chaturvedi	Private Secretary
5. Sh. Hoob Lal	Personal Assistant
6. Sh. Om Prakash	Personal Assistant
7. Sh. Mahendra Kumar	Assistant
8. Sh. Jai Janardan Singh	Assistant
9. Sh. Vir Singh Pal	Assistant
10. Sh. Deepak Vij	Stenographer (Grade-III)
11. Sh. Tridev Chaturvedi	Stenographer (Grade-III)
12. Mrs. Kaushalya Devi	Sr. Clerk
Skilled Supporting Staff	
1. Sh. Attar Singh	
2. Sh. Ram Singh	
3. Sh. Jagdish Singh	
4. Sh. Ram Din	
5. Sh. Pramod Kumar	
6. Sh. Munna Lal	

CHAPTER

14 MISCELLANEOUS

New Staff

1. Sh. R Vishnu - Scientist (Agroforestry)
2. Mrs. Alka Bharti - Scientist, Agril. Biotechnology
3. Sh. Y N Venkatesh - Scientist, Agril. Entomology
4. Dr. Sushil Kumar - Scientist, Agronomy

Promotion

- Sh. Birendra Singh, Assistant promoted to the post of AAO through Limited Departmental Competitive Examination ,w.e.f. 16th January, 2019.
- Sh. Vir Singh Pal, Sr. Clerk promoted to the post of Assistant through Limited Departmental Examination, w.e.f. 19th December, 2019.
- Smt. Kaushalya Devi, Jr. Clerk promoted to the post of Sr. Clerk w.e.f. 20th December, 2019.

Institute Joint Staff Council

New IJSC has been constituted for the period of 06/04/2019 to 05/04/2022.

Internal Inspection by the Team of IPAI

Internal Inspection was conducted by the Team of Institute of Public Auditors of India (IPAI), for the period of 2018-19 of the Institute.

Zonal Sports Meet

A contingent of 21 players participated in the ICAR-Western Zonal Tournament-2019 from 14th to 18th November, 2019 held at ICAR-CS & WRI, Avikanagar (Raj.). Sh. Atar Singh, SSS got First position in the cycle race.

Inter -zonal Sports Meet

Sh. J L Sharma, AO as a CDM and Sh. Atar Singh, SSS in Cycle race participated in the Inter- Zonal Sports Meet during 25th to 28th February, 2019 held at ICAR-Indian Veterinary Research Institute (ICAR-IVRI), Izatnagar - Bareilly (UP).

Retirement

- Dr. Anil Kumar, Pr. Scientist (Plant Pathology) & Director (A) retired on 31st December, 2019.
- Sh. B Singh, Chief Technical Officer (Farm Manager) retired on 31st December, 2019.

Transfer

- Dr. Mahendra Singh, Pr. Scientist (Agriculture Economics) has been transferred to ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi on 30th November, 2019.
- Dr. K B Sridhar, Scientist (Forestry) has been transferred to ICAR- Central Research Institute for Dryland Agriculture, Hyderabad (Telangana) on 30th November, 2019.
- Dr. Veeresh Kumar, Scientist (Entomology) has been transferred to ICAR- National Bureau of Agricultural Insect Resources, Bengaluru (Karnataka) on 12th February, 2019.

ANNEXURE-I

QUINQUENNIAL REVIEW TEAM
(01/04/2018 to 31/03/2023)

S.No.	Name	S.No.	Name
1	**Dr. K R Dhiman, (Chairman)** Former Vice Chancellor Dr. Yashwant Singh Parmar University of Horticulture and Forestry (Dr. YSPUH & FS) Solan (HP)	2	**Dr. A K Vashisht** Former ADG (PIM) Indian Council of Agricultural Research (ICAR), New Delhi
3	**Dr. Rajeshwar Chandel** Member, Executive Director Natural Farming Department of Agriculture Shimla (HP)	4	**Dr. A K Mohapatra** Former Professor Agronomy Odisha University of Agriculture and Technology (OUAT) Bhubaneshwar (Odisha)
5	**Dr. S J Patil** Professor & Head, Department of Silviculture and Agroforestry & Dean, Student Welfare Officer, University of Agricultural Sciences (UAS), Dharwad (KA)	6	**Dr. A K Handa** Pr. Scientist & Member Secretary ICAR-CAFRI, Jhansi (UP)

ANNEXURE-II

RESEARCH ADVISORY COMMITTEE

Dr. K Gurumurthi, Chairman
Former Director, IFGTB
62/4, Leela Apartments
Ponnayarjapuram

Dr. S K Dhyani
Senior Agroforestry Expert
World Agroforestry Centre (ICRAF),
Regional Office for South Asia,
C- Block, NASC Complex, DPS Marg
New Delhi-110 012

Dr. A K Mandal
Former Director, TFRI
Srikrishna Apartment, New Area,
Morabadi, Balihar Road,
Ranchi - 834 008 (Jharkhand)

Dr. S Bhaskar
Assistant Director General
(Agron./AF & CC)
NRM Division, ICAR,
Krishi Anushandhan Bhawan-II,
New Delhi- 110 012

Sh. Ashok Rajput
Village- Nandsiya, Mooth,
Post- Karjanva, Jhansi(UP)

Dr. Inder Dev
Pr. Scientist & Member Secretary,
ICAR- CAFRI,
Jhansi (UP)

Dr. R K Patnaik
Former Dean, CoF, OUAT, Bhubaneshwar
Flat Number 303, Gopal Residency
Kalpana Road, B.J.B. Nagar
Bhubaneswar - 751 014 (Odisha)

Dr. S D Bhardwaj
Former Dean,COF, YSPUHF, Solan
House No. 33, Scientist Colony,
P.O. Shamti,
Solan - 173 212 (HP)

Dr. B N Patel
Principal and Dean,
ASPEE College of Horticulture and Forestry,
Navsari Agricultural University,
Navsari - 396 450 (Gujarat)

Dr. R C Dhiman
General Manager
WIMCO Seedling Limited,
R&D Centre,
Bagwala, Kashipur Road,
Rudrapur - 263 153 (Uttrakhand)

Sh. Pradeep Saravgi
House No. 165, Purani Nazai
Jhansi(UP)

Two persons representing agriculture/rural interests on the Management Committee of the Institute in terms of Rule 66 (a) (5) for the period of their membership of the Management Committee

ANNEXURE-III

Institute Management Committee (IMC)
(2018-2021)

Dr. Anil Kumar (Chairman)
Director (A)
ICAR-CAFRI,
Jhansi (UP)

Dr. K P Mohapatra
Principal Scientist,
ICAR- RC-NEHR,
Barapani

Dr. Jagdish Tamak
HOD Plantations, ITC Limited,
Paperboard and Specialty Paper Division,
106, Sardar Patel Road,
Secunderabad-500 003 (Telengana)

The Assistant Director General (A, AF & CC)
NRM Division
Indian Council of Agricultural Research,
Krishi Anushandhan Bhawan-II
New Delhi-110 012

Director
Statistics and Crop Insurance,
Government of Uttar Pradesh,
Krishi Bhawan, Madan Mohan Malviya Marg,
Lucknow (UP)

Dean
Krishi Vidyalaya,
Raj Mata Vijyaraje Scindiya Krishi Vishwa Vidyalaya, Gwalior (MP)

Finance & Account Officer
ICAR- Indian Grassland & Fodder Research Institute,
Jhansi (UP)

Dr. C B Pandey
Principal Scientist,
ICAR- CAZRI,
Jodhpur (Rajasthan)

Dr. Harsh Mehta
Principal Scientist,
ICAR- IISWC,
Dehradun (Uttrakhand)

Dr. Inder Dev
Principal Scientist,
ICAR- CAFRI, Jhansi

Sh. Ashok Rajput
Village- Nandsiya, Mooth,
Post- Karjanva, Jhansi (UP)

Sh. Pradeep Saravgi
House No. 165,
Purani Nazai
Jhansi (UP)

Director Extension Services
Jawahar Lal Nehru Krishi Vishwa Vidyalaya,
Jabalpur (MP)

Sh. J L Sharma
A O & Member Secretary
ICAR-CAFRI,
Jhansi (UP)

ANNEXURE-IV

Institute Joint Staff Council

Chairman : Dr. R K Tewari, Director (A)				
Category	**Staff Side**		**Office Side**	
Administration	**Sh, Birendra Singh** Assistant	**Member, CJSC**	**Dr. R. K. Tewari** Pr. Scientist	Member
	Sh. Tridev Chaturvedi Stenographer	**Secretary, IJSC**	**Dr. Rajendra Prasad** Pr. Scientist	Member
Technical	**Smt. Shelja Tamrkar,** Sr. Technical Assistant	Member	**Dr. Inder Dev** Pr. Scientist	Member
	Sh. Kashi Ram Tech. Asstt. (Driver)	Member	**Dr. C K Bajpai** CTO	Member
Supporting	**Sh. Attar Singh** SSS	Member	**Sh. J L Sharma** A.O. & H.O.	**Member Secretary**
	Sh. Ram Singh SSS	Member	**Sh. S B Sharma** AF&AO	Member

Swachh Bharat Abhiyan

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