Biomass Resource Mapping in Pakistan

IMPLEMENTATION REPORT

December 2015

This report was prepared by Full Advantage Co. Ltd [Lead Consultant], Simosol Oy, VTT Technical Research Center of Finland and PITCO (Private) Ltd., under contract to The World Bank.

It is one of several outputs from the biomass resource mapping component of the activity "Renewable Energy Resource Mapping and Geospatial Planning – Pakistan" [Project ID: P146140]. This activity is funded and supported by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund administered by The World Bank, under a global initiative on Renewable Energy Resource Mapping. Further details on the initiative can be obtained from the ESMAP website.

This document is an **interim output** from the above-mentioned project. Users are strongly advised to exercise caution when utilizing the information and data contained, as this has not been subject to full peer review. The final, validated, peer reviewed output from this project will be the Pakistan Biomass Atlas, which will be published once the project is completed.

RENEWABLE ENERGY RESOURCE MAPPING:
BIOMASS [PHASES 1-3] - PAKISTAN

REPORT ON
PHASE 2 IMPLEMENTATION AND REVISED WORK PLAN FOR PHASE 3

Prepared by:
Full Advantage Co., Ltd. (FA), Thailand (Lead Consultant)
Simosol Oy, Finland
VTT Technical Research Center of Finland (VTT)
PITCO (Private) Limited, Pakistan
National University of Sciences and Technology (NUST) of Pakistan

Date: 23 December 2015

Country:

Pakistan

Project title and ID:

Renewable Energy Resource Mapping: Biomass [Phases 1-3] - Pakistan
Project ID: P146140

Implementing agency:

The World Bank (Pakistan) in close coordination with the Alternative Energy Development Board (AEDB) of Pakistan

Team of Consultants:

Full Advantage Co., Ltd (Thailand)
- Dr. Ludovic Lacrosse, Team Leader/Biomass Energy Expert
- Dr. Tran Quang Cu, Training Coordinator

Simosol Oy (Finland)
- Dr. Jussi Rasinmäki, Remote Sensing/GIS Expert
- Dr. Antti Mäkinen, Geospatial Energy Planning Expert
- Dr. Jussi Kollin, IT / Database Expert
- Dr. Jussi-Pekka Aittola, Biomass to Energy Conversion Planning Expert

VTT Technical Research Centre of Finland (Finland)
- Mr. Heikki Astola, Remote Sensing Expert

PITCO Pvt., Ltd. (Pakistan)
- Mr. Omar Malik, Country Coordinator
- Mr. Qazi Sabir, Local Project Manager
- Mr. Ahmed Ammar Yasser, Biomass Expert
- Mr. Muhammad Gulraiz Khan, GIS Expert
- Mr. Umer Kamal, Field Coordinator/Expert
- Mr. Muhammad Armughan, Field Coordinator/Expert
- Mr. Rashid Ahmed, Event Coordinator

National University of Sciences and Technology (NUST) of Pakistan
- Dr. Ehsan Ali, Project Principal Investigator
- Dr. M. Bilal Khan, Co-Principal Investigator
- Mr. Ajaz Ahmad, Crop Survey Coordinator

Date of report:

23rd December 2015

TABLE OF CONTENTS

List of Tables

List of Figures

LIST OF ACRONYMS

AEDB	Alternative Energy Development Board (Pakistan)
AO	Accounts Officer
APO	Assistant Project Officer
BUITEMS	Baluchistan University of Information Technology, Engineering & Management Sciences
DAO	District Agriculture Officer
ESMAP	Energy Sector Management Assistance Program
FA	Full Advantage Co., Ltd. (Thailand)
FAO	Food and Agriculture Organization
FP	Focal Person
GIZ	Gesellschaft fur Internationale Zusammenarbeit (Germany)
GIS	Geographic Information System
GoP	Government of Pakistan
IST	Institute of Space Technology (Pakistan)
IUB	Islamia University, Bahawalpur
M&E	Monitoring and Evaluation
MUET	Mehran University of Engineering & Technology
NUST	National University of Sciences and Technology (Pakistan)
PITCO	PITCO Private Limited (Pakistan)
PSMA	Pakistan Sugar Mills Association
RE	Renewable Energy
SAU	Sindh Agriculture University
Simosol	Simosol Oy (Finland)
SUPARCO	Space and Upper Atmosphere Research Commission (Pakistan)
TOR	Terms of Reference
UNIDO	United Nations Industrial Development Organization
WB	World Bank

1. INTRODUCTION

Pakistan is facing a large deficit in electricity supply. A report published by the Government of Pakistan (GoP) in 2013[1] showed that the electricity supply-demand gap has continuously grown over the past five years and has reached 4,500 to 5,500 MW in 2013. Such an enormous gap has led to load-shedding of 12-16 hours across the country.

GoP has set a target to reduce the electricity supply-demand gap to zero by 2017. In order to attain such ambitious target, the GoP has been endeavoring to exploit various options to meet the current and future anticipated electricity needs of the country. Conventional power generation has been the focus of the power master plan that includes large hydro power and fossil fuel-based thermal power projects. As Pakistan has a huge potential of renewable energy resources, the GoP is also promoting the use of renewable energies to increase their shares in total electricity mix of the country.

In order to support the GoP, the World Bank (WB) has been providing assistance towards continued development of renewable power (RE) generation (hydro, biomass, solar and wind). Therefore the energy sector meets electricity demand in an efficient, affordable and environmentally sustainable manner. One of these assistances is to develop RE resource maps for Pakistan. This project is being implemented by the World Bank in Pakistan in close coordination with the Alternative Energy Development Board (AEDB), a government agency of Pakistan. The project is funded by the Energy Sector Management Assistance Program (ESMAP), a global knowledge and technical assistance program administered by the WB and supported by 11 bilateral donors. It is part of a major ESMAP initiative in support of renewable energy resource mapping and geospatial planning across multiple countries.

Biomass resource mapping is one of component of the ongoing renewable energy resource mapping project in Pakistan. The objective of this biomass mapping component is to support the sustainable expansion of electricity generation from biomass. This is fulfilled by providing the national government and provincial authorities in Pakistan, and commercial project developers, with an improved understanding of the location and potential of biomass resources.

For this purpose, the World Bank has assigned a consulting Consortium, including Full Advantage Co., Ltd. (Thailand) as a lead consultant, Simosol Oy (Finland), VTT Technical Research Center of Finland, and PITCO Private Limited (local consultant) to develop a Biomass Atlas for Pakistan with a focus on Punjab and Sindh provinces as the starting points. NUST has been contracted to conduct the field survey and data collection on crop biomass residues.

The biomass resource mapping project consists of three phases:

- Phase 1: Project inception, team building, data source identification and implementation planning;
- Phase 2: Data collection/analysis and creation of draft biomass resource maps;
- Phase 3: Production and publication of a validated biomass resource atlas.

[1] *National Power Policy, Government of Pakistan, 2013.*

The present report is the Progress Report on "Phase 2 Implementation of the Biomass Resource Mapping for Pakistan". It covers the activities carried out in the period from March 1, 2015 to November 30, 2015. The report also includes the revised Work Plan for Phase 3 of the project.

The main activities of Phase 2 consisted in:

1. Remote data collection and analysis;
2. Preparation for field survey and data collection;
3. Conduct of field survey and data collection;
4. Data analysis and development of draft biomass atlas;
5. Conduct of stakeholder data validation workshop.

The implementation of these activities and their outputs are reported in sections 3, 4, 5, 6 and 7 respectively.

2. Expected Outputs and Summary of Achievements of Phase 2

2.1 Expected Outputs of Phase 2

According to the Terms of Reference (TOR), the expected outputs/deliverables of Phase 2 include:

- Creation of a comprehensive database for biomass resource mapping, including raw data files;
- Production of draft biomass resource maps;
- Organization of a stakeholder data validation workshop.

2.2 Summary of Achievements vs Expected Outputs

The expected outputs and the summary of achievements of Phase 2 of the project are presented in Table 1.

Table 1: Summary of achievements vs expected outputs of Phase 2

Activity	Expected outputs	Achievements
Remote data collection and analysis	• Remote data collected and analyzed	• Satellite images were acquired from Landsat 8 and were analyzed to produce the raw biomass cluster images for field observation and inspection. • A field inventory plan was created.
Preparation for field survey and data collection	• Training on field survey and data collection conducted	• MHG Biomass Manager was developed. • Required smartphone applications for navigation, data entry and data transfers were acquired. • Training on field survey and data collection was conducted on 7-9 April 2015 for 59 participants from 3 universities.

Conduct of field survey and data collection	• Field surveys conducted and data collected	• Field surveys were conducted and the data on crop biomass residues were collected in 166 tehsils of 44 districts in Punjab, Sindh, KPK and Baluchistan (12,450 farmers interviewed). • Field surveys were conducted and the data on industrial biomass residues were collected (178 sites). • GIS data of other driving components (road network, power T&D network, etc.) were acquired.
Data analysis and development of draft biomass atlas	• A comprehensive database necessary for biomass resource mapping, including raw data files elaborated • Draft biomass resource maps developed	• The collected data were processed and integrated into a comprehensive database. • Draft biomass resource maps were produced.
Conduct of stakeholder data validation workshop	• A stakeholder data validation workshop conducted	• A stakeholder data validation workshop was conducted on 26 November 2015

2.3 Major Deviations and Mitigations

There have been some deviations from the Implementation Plan for Phase 2 that was approved by the World Bank (WB) in March 2015. They are as follows::

- ***SUPARCO issue (see section 5.3):*** There was not much hope left to get access to SUPARCO's land use classification datasets when Phase 2 Implementation Plan was submitted. Despite regular contacts from AEDB and PITCO, communications he with SUPARCO got to a dead end. It was therefore decided to stick to the original plan that the land area would be mapped based on Landsat 8 images.
- ***Delay in data collection:*** The last part of the field survey had to be postponed due to several reasons, the main one being the lack of upfront cash available at NUST level to conduct the training workshop in Quetta (Baluchistan) and the final field surveys in KPK and Baluchistan provinces. An extension of duration of two months was granted by the World Bank. The field survey was finally completed in October 2015.

3. Remote Data Collection and Analysis

3.1 Gathering of Satellite Images

The first step in the remote data collection and analysis phase was gathering the satellite images. In order to achieve the proposed goals it was decided that eight time instances of images encompassing the entire territory of Pakistan would be needed. Each instance would represent the beginning and end of the Rabi and Kharif cropping seasons in the country and also the transition periods between them. In total the analysis used 368 images, or 6 sets containing 46 images each, image acquisition date ranged from March 2014 to April 2015. Figure 1 shows the coverage of the Landsat 8 images imposed over the map of Pakistan.

The images used were Landsat 8 Operational Land Imager (OLI) gathered from the Landsat Archive Collections. Initial Image selection was made using the available browse images from USGS Global Visualization Viewer[2]. Once the preliminary selection was completed, Level 1 GeoTIFF Data Product image archives were ordered and downloaded from USGS Earth Explorer[3].

As a rule, images presenting the least cloud cover within the specified time frame were selected.

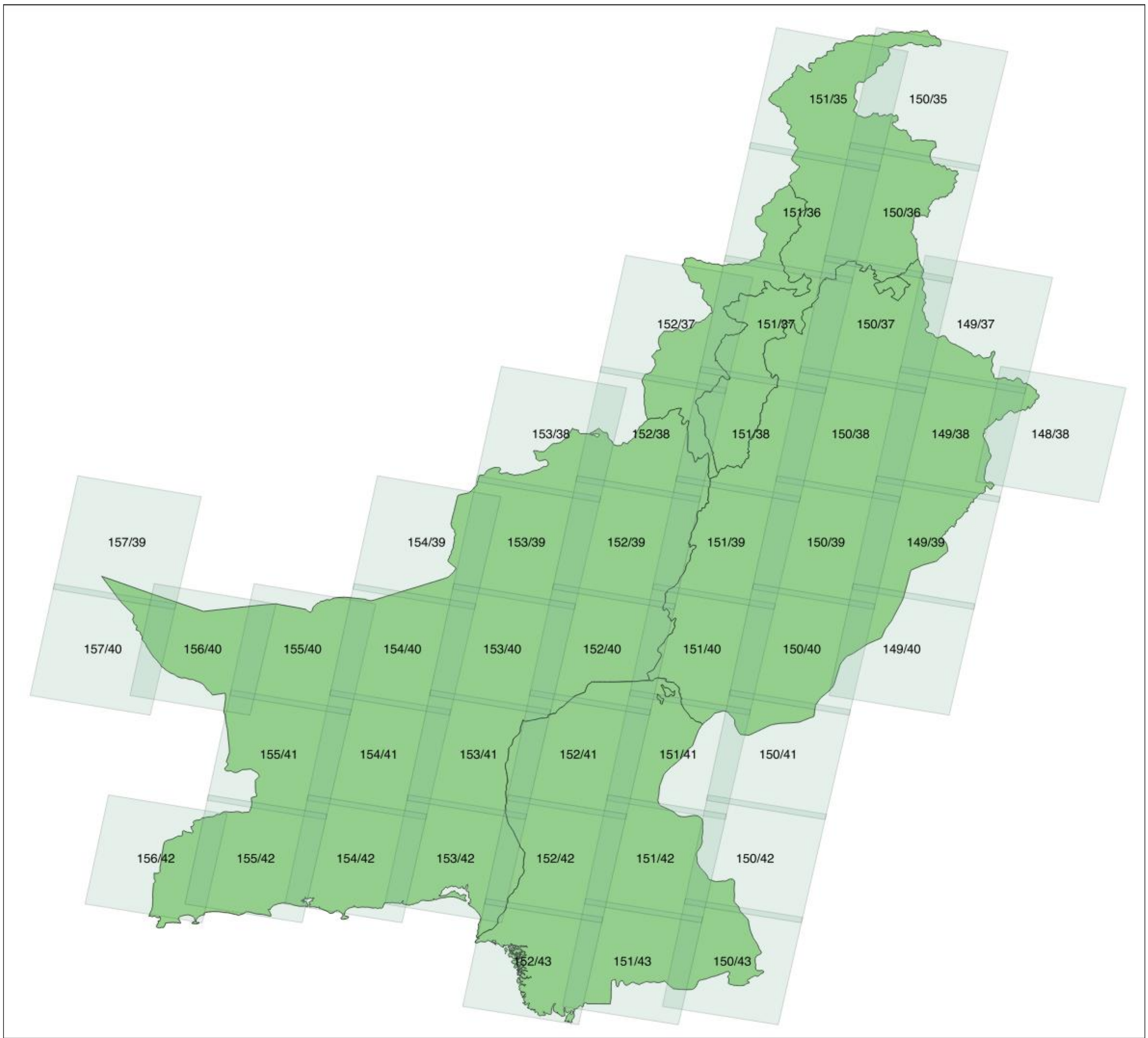

Figure 1: Landsat 8 image tiles used in the analysis.
(The numbering relates to the global path and row grid for the Landsat data)

[2] *http://glovis.usgs.gov*
[3] *http://earthexplorer.usgs.gov*

3.2 Analysis of Satellite Images

The satellite image processing consisted of 8 stages described below. We executed these steps to the six different seasonal image sets described above.

The satellite image analysis stages:

1. ***Image unpacking:*** the unpacking stage extracts the satellite image data and its metadata from the distribution archive downloaded from USGS Earth Explorer. We executed this with the Envimon pre-processing software developed by VTT Technical Research Centre of Finland.

2. ***Cloud masking:*** we created a cloud mask for each of the satellite images by combining the cloud mask produced with the Fmask[4] software with manual delineation of clouds, cloud shadows and haze. Usually the Fmask produced mask was augmented with the manual mask, but in some cases the quality of the automatically created mask was so low that it was replaced completely with the mask created with visual analysis of the images.

3. ***Analysis area masking:*** we also created an analysis area mask based on visual interpretation of the satellite images. The purpose of this mask is to target the land cover classification to the areas that are of interest to the task at hand, i.e. to the areas used for agricultural production. This should allow for better classification accuracy for the target areas.

4. ***Radiometrical calibration:*** images taken at different times are taken under different optical conditions. Therefore their radiometry, i.e. how the reflectance of sun radiation at different wavelengths is recorded by the sensors in the satellite must be calibrated so that similar pieces of land have similar reflectance values on different images. We did this by selecting a reference image and calibrating other images to it based on common pixels, not covered by the cloud mask, between image pairs.

5. ***Image and mask mosaicking:*** Once the radiometry of all individual images was calibrated, the images were mosaicked, i.e. "stitched" together into a one seamless image covering the whole analysis area. This is illustrated in Figure 2. The same procedure was executed for the cloud and analysis masks, so we ended up with a single mask showing areas that had clear pixels on the area of interest. An example is shown in Figure 3.

[4] *https://code.google.com/p/fmask/*

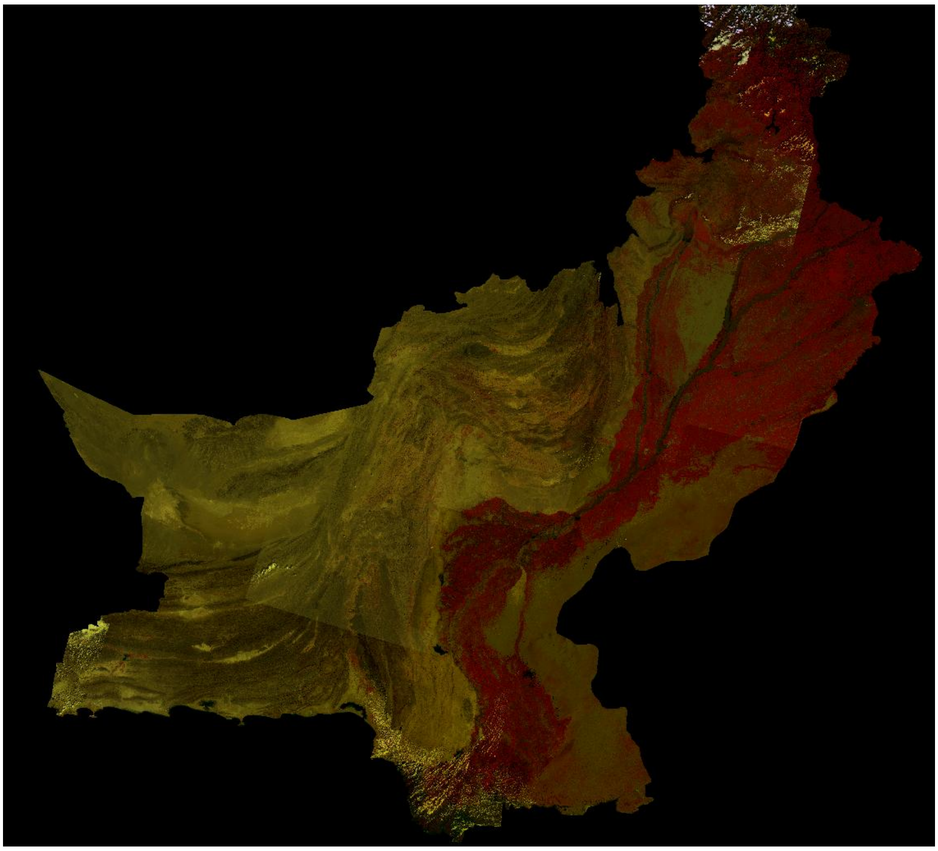

Figure 2: False color image mosaic for the late Kharif season dataset (bands used: blue, red, near-infrared)

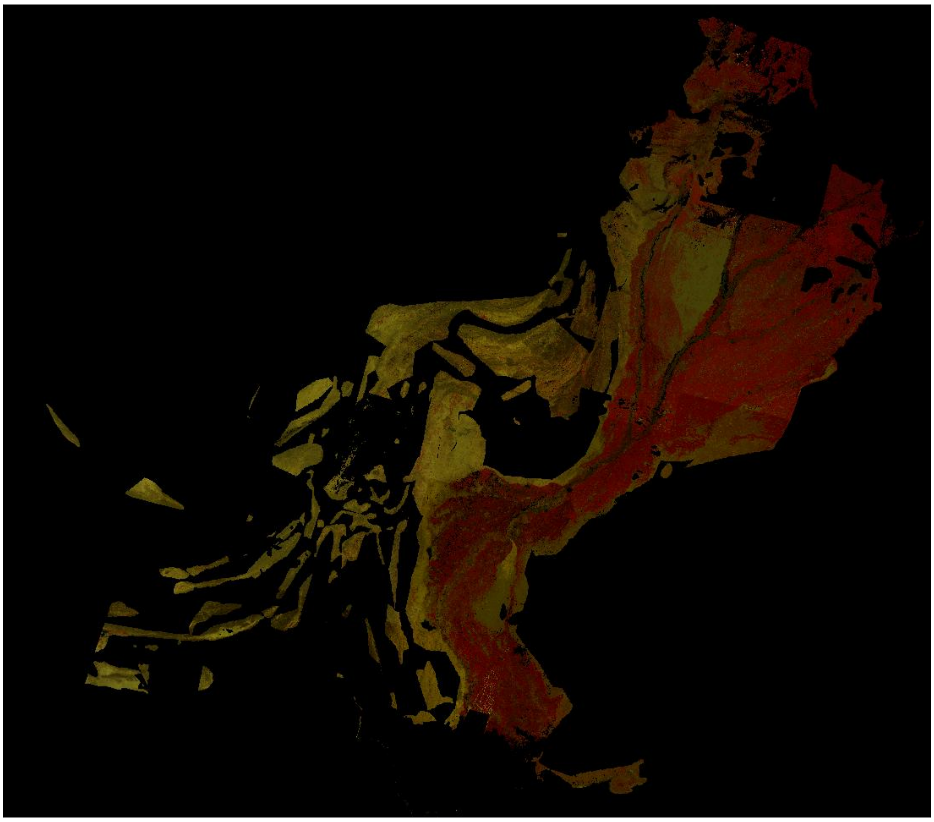

Figure 3: False color late Kharif dataset mosaic with the combined analysis and cloud mask applied

6. ***Cluster analysis:*** Using the reflectance information on blue, green, red, near-infrared and short-wave infrared bands, the pixels covering the cloud-free analysis area were classified into clusters. Each cluster is characterized by pixels having similar reflectance values for the analysis bands. The clustering was done with the Probability software developed by VTT Technical Research Centre of Finland.

7. ***Ground reference data processing:*** individual field observations recorded with the MHG Mobile software during the field survey (see below) were processed into "per cropping season reference observations" (geographic coordinates for the observation, cultivated crop).

8. ***Land cover classification:*** We combined the cluster analysis results and the reference observations into a crop level crop classification for all clear pixels over the analysis areas. This step was again done with the Probability software developed by VTT Technical Research Centre of Finland. The land cover classes we used were wheat, cotton, rice, maize, sugarcane, "other crops" (all other crops pooled as a single land cover class), water, urban area, natural vegetation and bare area. This classification was done independently for each of the image sets in the time series (see Figure 4). Combining these individual classifications to the final per season classification remains to be done during Phase 3.

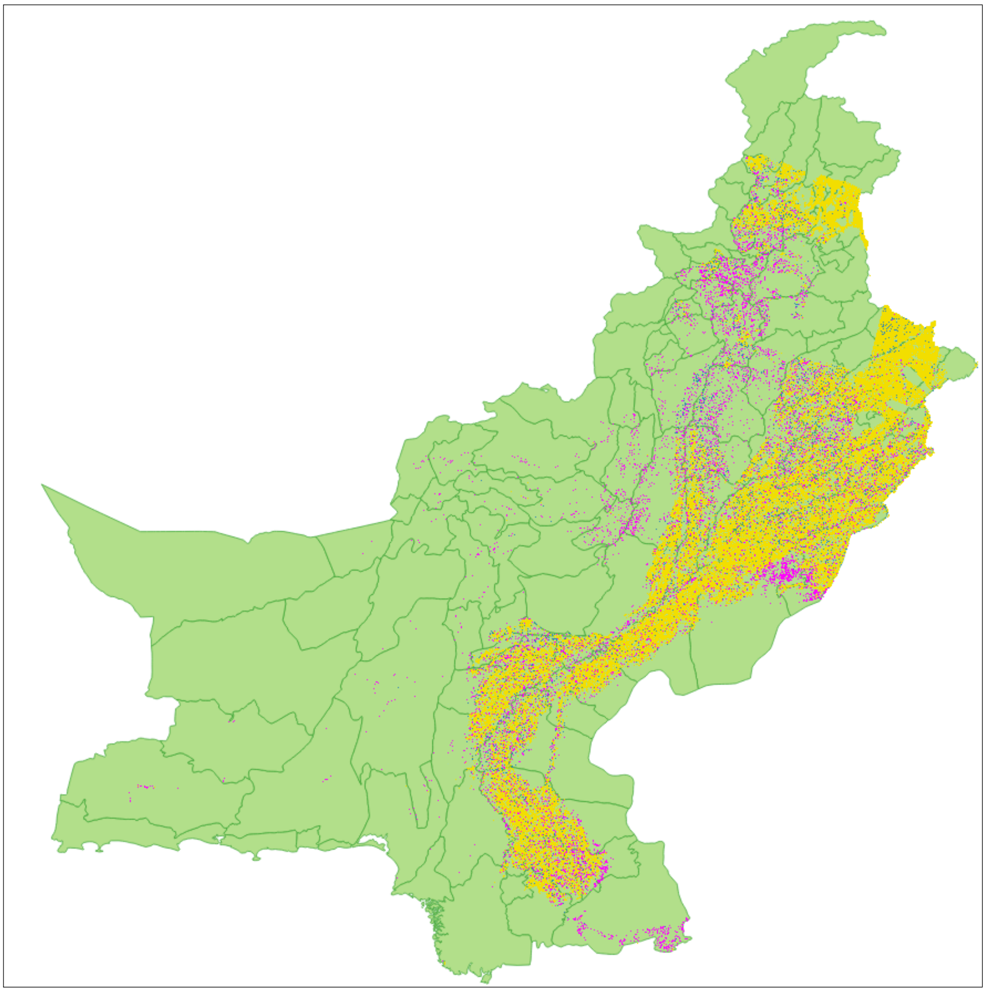

Figure 4: Late Kharif dataset crop classification, showing different crops with different colors

The remaining steps for Phase 3 atlas finalization are:

- Improvement for the radiometric calibration; current results still have some between images radiometric differences that affect the crop classification results.
- Combination of the single time season crop classifications into a single two-season crop classification to improve classification results.

4. Preparation for Field Survey and Data Collection

4.1 Development of the Survey Form for MHG Mobile App

We implemented a smartphone based field survey questionnaire using the MHG Mobile app[5]. The form had sections for questions about the respondent, farm, crops cultivated on the farm, harvest residue marketing efforts, and finally about a particular reference field for the satellite image analysis. The detailed composition of the survey form is documented in Attachment 1.

To accompany the mobile field survey form we developed a data validation routine where the survey data was daily downloaded from the backend system of MHG Mobile, stored in an Excel file containing all the survey data collected for that day. A validation routine was also run on the data being written to the Excel file. In case of any invalid data was detected by the routine, the Excel file also had the invalid data highlighted and the reason for non-validity was written in the file as well.

The same validation rules, mainly relating to crop yield levels, and harvest residue utilization pattern data, were also applied a second time when the district level final survey results were compiled. The validation rules were fine-tuned over the progress of the survey.

4.2 Training Workshop on Field Survey and Data Collection

A training workshop on field survey and data collection of crop biomass residues in Pakistan was conducted in Islamabad on 7-9 April 2015. The event was held at the Center for Advanced Studies in Energy (CAS-EN) of the National University of Sciences and Technology (NUST). The objective of the training workshop was to provide hands-on training to the field surveyors for conducting surveys using 3G smartphones and Android applications designed and recommended by Simosol, Finland.

The training workshop consisted in three broad sessions spread over three day. On the first day, an introductory session was organized at NUST, H-12 campus, followed by a technical session. On the second day, a pre-testing activity was organized to test the survey methodology while on third day, an internal stakeholders meeting was held for discussing future strategies.

Fifty nine (59) participants have been trained of which 14 participants from NUST, 24 from the University of Agriculture in Peshawar and 21 from the University of Agriculture in Faisalabad.

The completion report on this training workshop is provided in Attachment 2.

[5] *https://play.google.com/store/apps/details?id=com.mhgsystems.ui*

5. CONDUCT OF FIELD SURVEY AND DATA COLLECTION

5.1 Crop Biomass Survey and Data Collection

5.1.1 Methodology of Crop Biomass Survey

Survey Strategy:

The estimation of crop residues in all four provinces in one crop season was a big challenge. It was aimed to provide an updated knowledge of biomass availability in Pakistan to the potential investors for the promotion of biomass to electricity. A fast track survey strategy was designed by establishing collaboration with six universities in different regions of Pakistan and provincial agricultural departments in all four provinces.

This strategy aimed to address the issues of different languages in different regions and community level interactions for detailed and friendly communication during survey activities. Survey staff were carefully selected, and division of tasks was made based on the expertise in IT, statistics, field work and proficiency in more than one/two regional languages. All arrangements were made in a timely manner to avoid any problem while all issues were addressed without compromising on the quality of work. Completion of this project can contribute purposefully towards management of the energy crisis in Pakistan. The detailed methodology of the survey can be elaborated as follows (Figure 5).

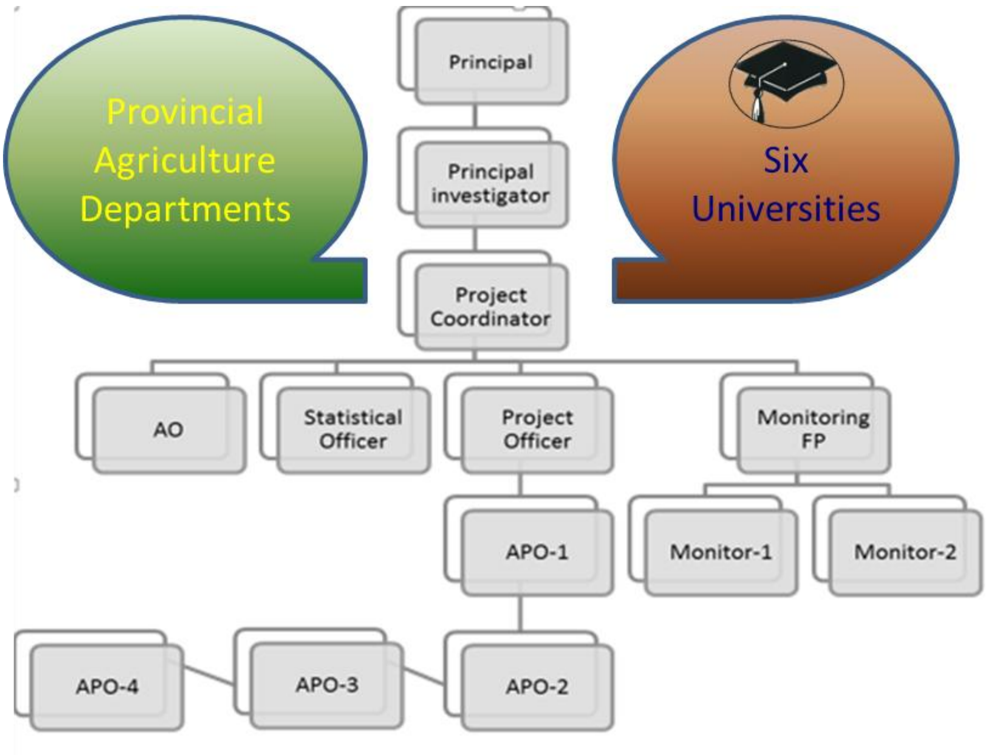

Figure 5: Staffing Strategy

Staffing Strategy:

NUST deployed field staff to cover at least two provinces at a time. The following diagram shows staff deployment:

Preparation of TORs of the Project Field Staff:

NUST prepared and issued clearly defined and focused TORs for the field staff. Major responsibilities entrusted to them included the following:

- Plan and conduct survey in 166 tehsils of the 44 targeted districts in all the four provinces;
- Undertake pre-survey logistics assessment visit to every district. If any district does not appear appropriate because of security reasons, suggest an alternate district in consultation with the concerned University and the Agriculture Department;
- Coordinate with the concerned Universities for provision of students to work as surveyors;
- Participate in a 2-day training workshop in Islamabad held on April 7-8, 2015;
- Provide on-the-job training and supervision to the surveyors during data collection;
- Obtain any required clearances for survey from government agencies;
- Submit a survey plan for each district separately giving dates for each tehsil;
- Conduct survey on the scheduled dates;
- Make payments in the field in cash and submit financial documentation electronically and in hard copies;
- Carry the mobile phones, distribute to the Surveyors during survey, collect back after the survey and return to NUST.

Pre-Survey Logistics Assessment:

The project staff personally visited all the targeted districts and obtained the following information prior to carrying out the survey:

- Met with the District Agriculture Officers (DAO) and requested them to facilitate the survey and assign someone to coordinate with NUST. Got the mailing address, email address, land line and mobile numbers of these persons.
- Got information about five major crops in the district. If five crops did not exist, got information about any major crops cultivated in the tehsil.
- Requested the DAOs to identify 75 potential respondent farmers for each tehsil of the district. The list included their names, addresses and mobile numbers.
- The 75 farmers identified by the DAO were divided as: five crops, five farmers with more than 25 Acres and ten farmers with less than 25 acres of land for each crop. If five farmers with more than 25 acres in a particular crop did not exist, smaller land holders were interviewed. The fixed number of interviews for each tehsil was 75.

- The farmers should be from three to four Union Councils in each tehsil and four to five villages in each Union Council.
- Identified accommodation for the surveyors on the dates of survey.
- Identified local transport for carrying the surveyors from their place of stay to the survey sites.

Cash Transactions:

The project involved hundreds of payments on daily basis spread over multiple tehsils, districts and provinces. NUST devised a special arrangement for making cash payments in the field and implemented it after approval from FA. The following payments were made in the field in cash:

- Honorarium to the Surveyors;
- Honorarium to Agriculture staff;
- Food for Surveyors;
- Accommodation for Surveyors;
- Transport for Surveyors;
- Any other expenses necessitated in the field.

Training of the Students of other Universities:

As agreed in the contract with FA, NUST engaged six universities to provide their students for conducting this survey. NUST requested the Vice Chancellors (VCs) of the respective universities to nominate a Focal Person for coordinating with NUST for participating in the survey. The VCs nominated the Focal Persons, who identified and nominated students from their respective universities to conduct this survey. Mostly, PhD and Master level students of the following universities participated in the survey:

1. Agriculture University, Faisalabad
2. Agriculture University, Peshawar
3. Islamia University, Bahawalpur (IUB)
4. Baluchistan University of Information Technology, Engineering and Management Sciences (BUITEMS)
5. Sindh Agriculture University (SAU), Tandojam, Hyderabad
6. Mehran University of Engineering & Technology (MUET), Jamshoro

NUST provided training to the nominated students. The students of the Agriculture University, Faisalabad and the Agriculture University, Peshawar were trained at NUST, Islamabad, whereas training workshops were conducted in other universities. The training workshops were conducted on the following dates:

- Training Workshop in NUST, Islamabad — 7-8 April, 2015
- Training Workshop in IUB, Bahawalpur — 28 April, 2015
- Training Workshop in SAU, Tandojam — 4 June, 2015
- Training Workshop in MUET, Jamshoro — 5 June, 2015
- Training Workshop in BUITEMS, Quetta — 15 September, 2015

The trained students were picked from their respective universities and taken to the survey sites. All sort of logistic support was provided to them including, but not limited to, the boarding, lodging, meals, transport, mobiles, protection, and facilitation in interacting with the farmers. The reports on the training workshop in IUB, SUET, MUET and BUITEMS are attached as Attachment 3.

Involvement of Provincial and District Agriculture Departments:

The involvement of the provincial Agriculture Departments was ensured. NUST wrote letters to the Provincial Secretaries of Agriculture of all four provinces, who endorsed these letters to the Director Generals of Agriculture Extension, who designated the Deputy Directors responsible at the district level. The Deputy Directors assigned field staff with each team of surveyors sent by NUST. Usually, 6 to10 members of the field staff were engaged in a district.

5.1.2 Monitoring and Evaluation of Crop Biomass Survey

Monitoring and Evaluation by NUST:

The Project Monitoring Staff of NUST was responsible to ensure that the survey was conducted by the trained students of the participating universities and on the dates and locations pre-determined in consultation with the Deputy Directors of Agriculture in the respective districts.

The project required that the surveyors complete a digital questionnaire on Android mobiles that would then be sent to Simosol in Finland. The uploaded data was sent back to NUST for validation of minimum and maximum yield limits and for completion of any missing information on the second or third day of the survey. NUST Monitors assisted in validating the data. The validated and verified data were eventually sent back to Simosol. That procedure continued until data were finally accepted. The role of NUST in a given district was over once Simosol gave final acceptance of the data.

Monitoring and Evaluation by PITCO:

Based on the Implementation Plan of Phase 2, PITCO was assigned to be responsible for the monitoring, evaluation and verification of the crop biomass survey data and activities carried out by NUST.

The methodology and approach adopted by PITCO for carrying out the M&E activities is presented in Figure 6.

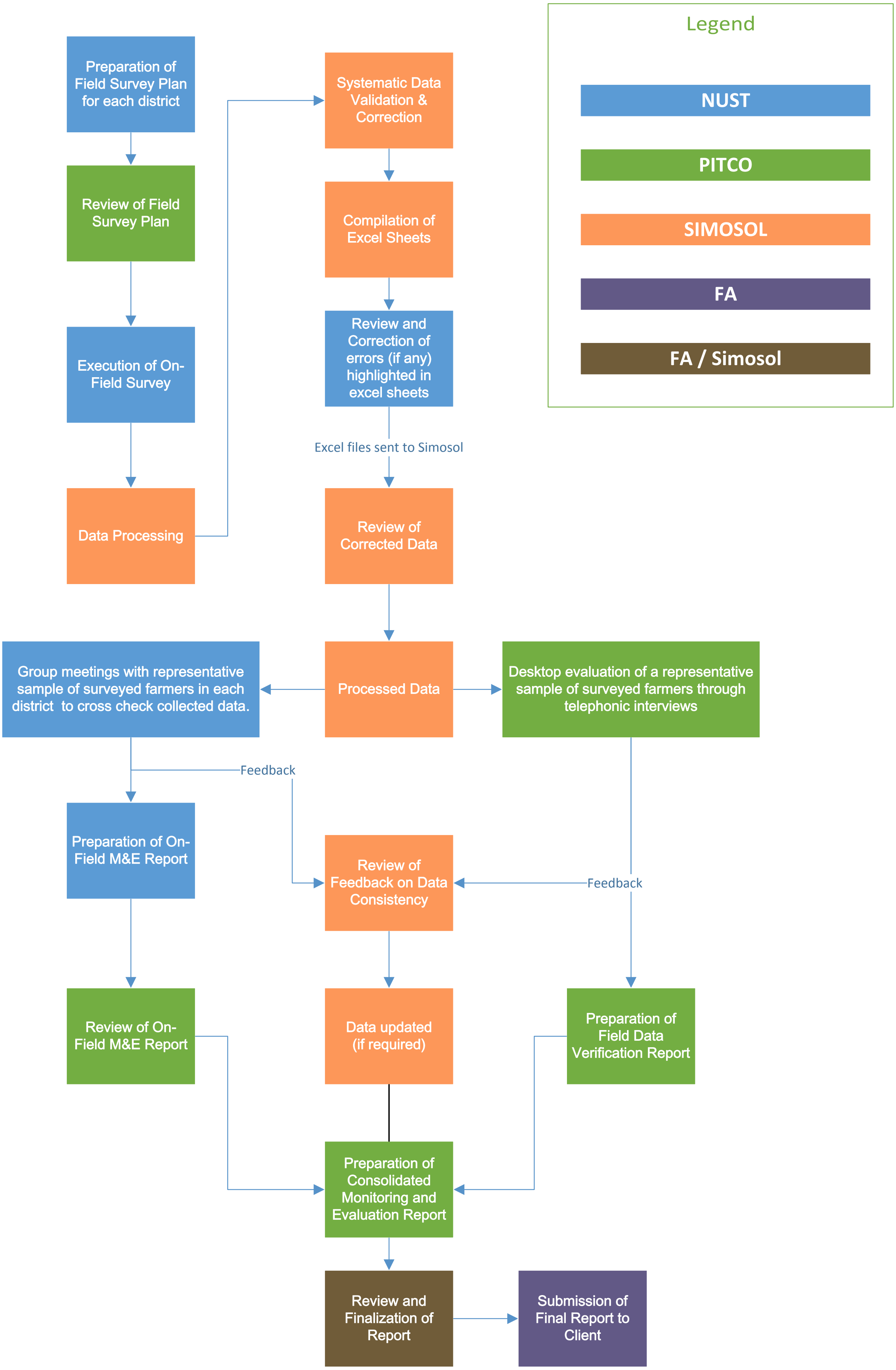

Figure 6: PITCO's M&E Methodology and Approach

A total of 967 farmers (about 7.8% of total farmers surveyed by NUST) were contacted by PITCO through phone calls for data verification. Out of these, 136 datasets were excluded by NUST before sending the raw data to Simosol for final validation. As a consequence, they were not part of the final validated dataset provided to PITCO by Simosol. Hence, the error analysis summarized in the table below is based on a comparison between the remaining 831 surveyed farmers done by PITCO. This corresponds to the same set of farmers (831) surveyed by NUST which were used for the final validated datasets for biomass mapping.

The following key data were verified during each call:

- Confirmation of survey
- Area of cultivation
- Crops harvested
- Yield of crops
- Use of biomass
- Price of biomass (if sold)
- To whom biomass is sold

The results of data verification are given in Table 2. The full report on M&E of field survey and collection of crop biomass data is provided in Attachment 4.

Table 2: Summarized results of data verification

M&E data	Number of datasets with errors found	% of total M&E samples
Incorrect name of crop(s) cultivated by farmer	44	5.3%
Name of crop(s) not specified	24	2.9%
Incorrect crop(s) yield	42	5.1%
Incorrect crop(s) residue price	53	6.4%
Incorrect crop(s) residue usage	42	5.1%
Survey team didn't visit the farmer	26	3.1%

Of all the error types, the only significant error types, which can potentially impact the crop survey results, are “Incorrect crop (s) yield”, “Incorrect crop (s) residue usage”, and “Survey teams didn’t visit the farmer”. However, with regard to the biomass field survey conducted by NUST, these errors are still within reasonable range. Furthermore, these data verification results will be incorporated in analysis of confidence limits of the final biomass atlas.

The error analysis is provided in Table 3.

Table 3: Error Analysis

Error Type	Possible Reasons for Error	Significance of Error
Incorrect name of crop(s) cultivated by farmer	• Farmer reported the wrong crop type or there was a communication error between the farmer and the surveyor • The surveyor erroneously selected the incorrect entry while recording the survey data in the app	Not Significant
Name of crop(s) not specified	• Non-conventional crop reported by the farmer. • The surveyor erroneously selected the incorrect	Not Significant

	entry while recording the survey data in the app	
Incorrect crop(s) yield	• Farmers have a tendency to understate their crop yields to avoid taxation or raise in land rent • The surveyor entered the wrong value while recording data	Significant
Incorrect crop(s) residue price	• Farmers indicated the price in the wrong units (PKR/maund instead of PKR/ton) • Farmers are generally unaware of the market prices of the biomass residues and the values reported by them are highly unrealistic.	Not Significant
Incorrect crop(s) residue usage	• Seasonal variation in the residue usage pattern	Significant
Survey teams didn't visit the farmer	• The survey team didn't visit the farmer • Farmers provided the contact details of their landlord or some other person who did not know about the visit of NUST surveyor	Significant

Based on the error analysis, it is concluded that the biomass field survey data gathered by NUST can be considered reliable and accurate.

A separate final data verification step will also be executed for the crop information during production of the final biomass atlas. The survey questionnaire included a "reference field" for which the three latest crops were recorded and a photograph was taken. For cases where the photograph does not match the recorded crops, the survey data will be excluded from the atlas modelling data.

5.1.3 Results of Crop Biomass Survey

The crop biomass survey was completed and the final report was sent to FA on 14 October 2015. The collected data were regularly submitted to Simosol in the form of Excel files.

The number of surveyed districts and tehsils and the number of farmers interviewed in each of 4 provinces are presented in Table 4. A tabular chronology of data collection is provided in Attachment 5.

Table 4: Summary of number of districts, tehsils and farmers surveyed

Province	Number of districts surveyed	Number of tehsils surveyed	Number of farmers interviewed
Punjab	18	62	4,650
Sindh	13	67	5,025
KPK	9	26	1,950
Baluchistan	4	11	825
Total	**44**	**166**	**12,450**

5.1.4 Lessons Learned from Crop Biomass Survey

Availability of biomass involves number of factors including consumption of biomass at domestic level, feed for animals and fuel for industries.

The crop biomass survey activity was facilitated by the involvement of universities with qualified students and focal persons from academia. Students from different regional universities were surveying within their own region, so they were well aware of the local customs and regulations.

Agriculture officers have deep contacts with farmers facilitating the communication between farmers and students. The advanced survey tools designed by Simosol helped a lot in making the survey easier. This activity was also helpful to create awareness regarding importance of biomass among students, teachers and farmers.

5.2 Industrial Biomass Survey and Data Collection

PITCO was assigned to carry out the industrial biomass survey (including municipalities, dairy farms, power plants, industrial organizations, governmental departments).

The purpose of the activity was to survey industrial sites utilizing biomass based feedstock for energy production and producing secondary crop residues as part of their industrial processing chain.

The type and amount of secondary crop residue produced would be mapped together with the amount that is actually used and the energy conversion technology. For the industrial sites using biomass, the type and amount of biomass used and the energy conversion technology in use would also be mapped.

5.2.1 Methodology of Industrial Biomass Survey

PITCO interacted with several industrial associations for collection of biomass generation and consumption data for various industries. Furthermore, detailed questionnaires were sent to major industries for collection of relevant data.

PITCO identified the major industries through the list of members provided by industrial associations and from other publicly available sources. Furthermore, information regarding the industries using biomass for energy generation was collected from the local industrial boiler manufacturers/suppliers. Data were collected from these industries through site visits, follow-up calls and e-mails.

Some of the main questions used in the questionnaires were:

- Biomass residue generation;
- Excess quantity available (current market price for feedstock and transport cost, if applicable);
- Availability period (months);
- Biomass residue consumption;
- Type of technology used for biomass-based power generation.

Figure 7 highlights the methodology and the activities undertaken by PITCO for conducting the industrial biomass survey:

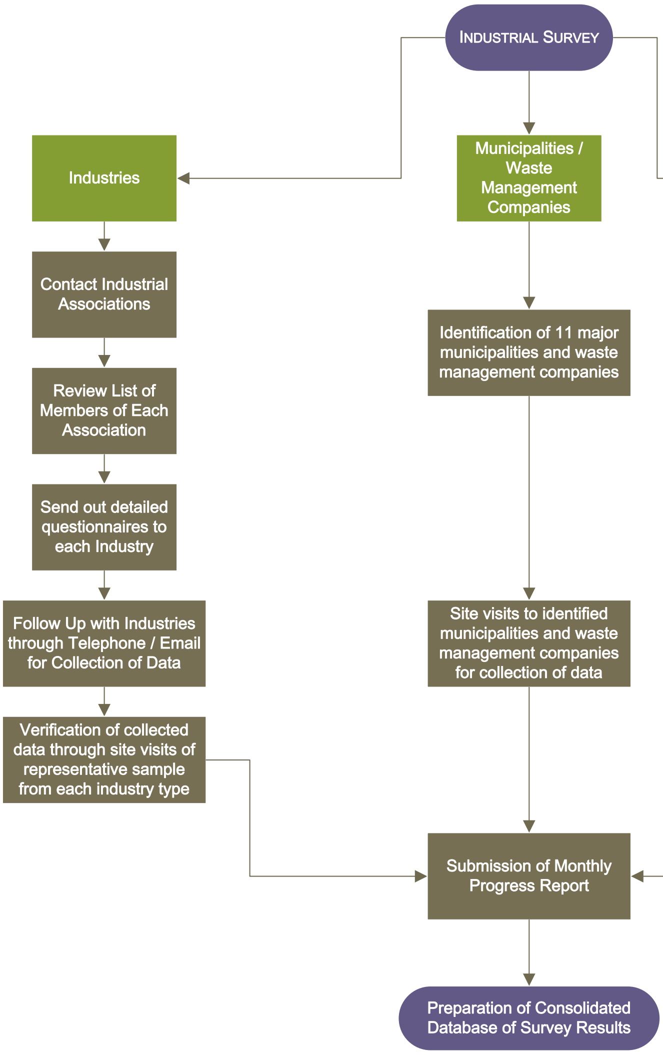

Figure 7: Methodology of Industrial Biomass Survey

5.2.2 Results of Industrial Biomass Survey

PITCO contacted 587 industries and associations for collections of data. Summary of the industries/organizations contacted and the data collection activities conducted by PITCO are given in Tables 5 and 6.

Table 5: Summary of contacted industries/organizations

Sector	Total Contacted[6]	Visits
Textile	209	8
Rice	176	34
Cement	27	1
MSW	11	10
Power Plants	16	10
Sugar Sector	84[7]	9
Dairy	19	2

[6] Each industry/association was contacted, on average, 4-5 times through calls and emails.
[7] Based on information from PSMA, there are 88 existing sugar mills in Pakistan, out of which 3 are non-members of PSMA and 1 is non-operational.

Food Processing	4	3
Paper and Pulp	26	2
Wood Processing	3	2
Associations/Organizations	12	10
Total	**587**	**91**

PITCO received data from 178 industries/organizations. Summary of the data received through various sources is given in the table below:

Table 6: Summary of data collection sources

Sector	Total Data Collected	Email	Follow-up calls	Site Visits	Publicly Available Information
Textile	**21**	1	9	8	3
Rice	**66**	1	31	34	
Cement	**6**	3	0	1	2
MSW	**11**	0	1	10	
Power Plants	**12**			10	2
Sugar Sector	**35**		26	9	
Dairy	**5**	2	1	2	
Food Processing	**3**			3	
Paper and Pulp	**4**	1		2	1
Wood Processing	**3**		1	2	
Associations[8]	**12**		2	10	
Total	**178**	**8**	**71**	**91**	**8**

Furthermore, PITCO prepared a detailed list of industries all across Punjab and Sindh for the purpose of mapping the industrial spread in Pakistan. The list is based on both publicly available information such as industrial chamber data (for Industries in Punjab only) as well as Associations' member lists which form the basis of list of industries in Sindh, KPK and Baluchistan as there are hardly any publicly available data and/or information as far as spread of industries in these provinces is concerned.

Summary of industrial spread, based on the collected data, is shown in Table 7.

Table 7: Industrial spread summary

Industry Type	Baluchistan	Federal Capital	KPK	Punjab	Sindh	Grand Total
Cement	1	1	7	11	9	29
Food Processing				4		4
Paper & Pulp				123		123
Printing				1		1
Rice				1772	391	2163
Sugar			8	45	35	88
Textile		4	11	1583	97	1695
Wood Processing				85		85
Grand Total	**1**	**5**	**26**	**3623**	**531**	**4186**

The detailed report on the industrial biomass survey is provided as Attachment 6.

[8] Associations provided only the lists of their members.

5.2.3 Lessons Learned from Industrial Biomass Survey

1. Industrial Associations in Pakistan are purely administrative bodies dealing mainly with policy level issues. With the exception of few, none of these has statistical/operational data of its member Industries.
2. Member lists provided by each Industrial Association (except PSMA) do not represent total number of industries for the respective sector.
3. Industrial Associations lack the requisite capacity to gather data from its members. Hence, no help was offered to PITCO in this respect.
4. Of all the industries contacted, only few (less than 2%) responded to the e-mails containing data collection requests.
5. Most of the data were collected through personal connections within the industrial sector as well as follow-up phone calls.
6. Despite the fact that the project benefits were clearly communicated to each industrial sector, most of the industries are reluctant to share biomass generation/consumption data.
7. Site visits for data collection/data verification visits had a 99% success factor.

5.3 GIS Data of other Driving Components

The consortium requested SUPARCO to provide the following data/information:

1. The segment-based land use classification executed for FAO as a vector dataset from the Pakistan Land Cover Mapping initiative. The current coverage of the classification, i.e. Sindh and Punjab, and access to the further results as they are delivered to FAO.
2. The Rabi and Kharif crop species level classification/mask raster (or in vector format if this classification was also segment-based) dataset based on the pan-sharpened multispectral SPOT-5 data classification from the Crop Situation and Forecast monthly bulletin. Latest available results are needed. In relation to this, is it possible for IST/SUPARCO to provide us continuous access to the base crop classification results so that we may establish a process that enables to keep the Biomass Atlas up to date by the Atlas hosting party within GoP?
3. High resolution digital elevation model (DEM), preferably better than 30m spatial resolution.
4. Nation-wide road dataset at highest existing detail level, vector dataset.
5. Natural water body network and irrigation channel network, vector dataset.
6. Power Transmission system infrastructure, vector dataset
7. Urban area delineations, vector or raster dataset. (already part of (i) for Punjab and Sindh).
8. Security area delineations, vector dataset.
9. Protective and conservation area delineations, vector dataset.

However, despite the best efforts from WB/AEDB and PITCO, none of the above requested data/information was provided by SUPARCO.

Power transmission infrastructure data was provided by PITCO. The datasets for natural water body network and irrigation channel network, and road network were collected from online sources:

- Road network: Open Street Map[9] and UNOCHA Pakistan[10]
- Water networks: UNOCHA Pakistan[11]

Road network mapping was also part of the field survey. The survey teams mapped the roads they travelled to get to the farms using mapping software[12] on their smartphones, thus producing accurate samples of roads connecting specific farms to regional urban centers. This data will be utilized in Phase 3 for the road network density modeling.

6. Data Analysis and Development of Draft Biomass Atlas

The first stage of the development of draft biomass atlas is illustrated in Figure 8. The first step of the analysis was the creation of the land cover classification. The details for this step are given in chapter 3.2 of this document.

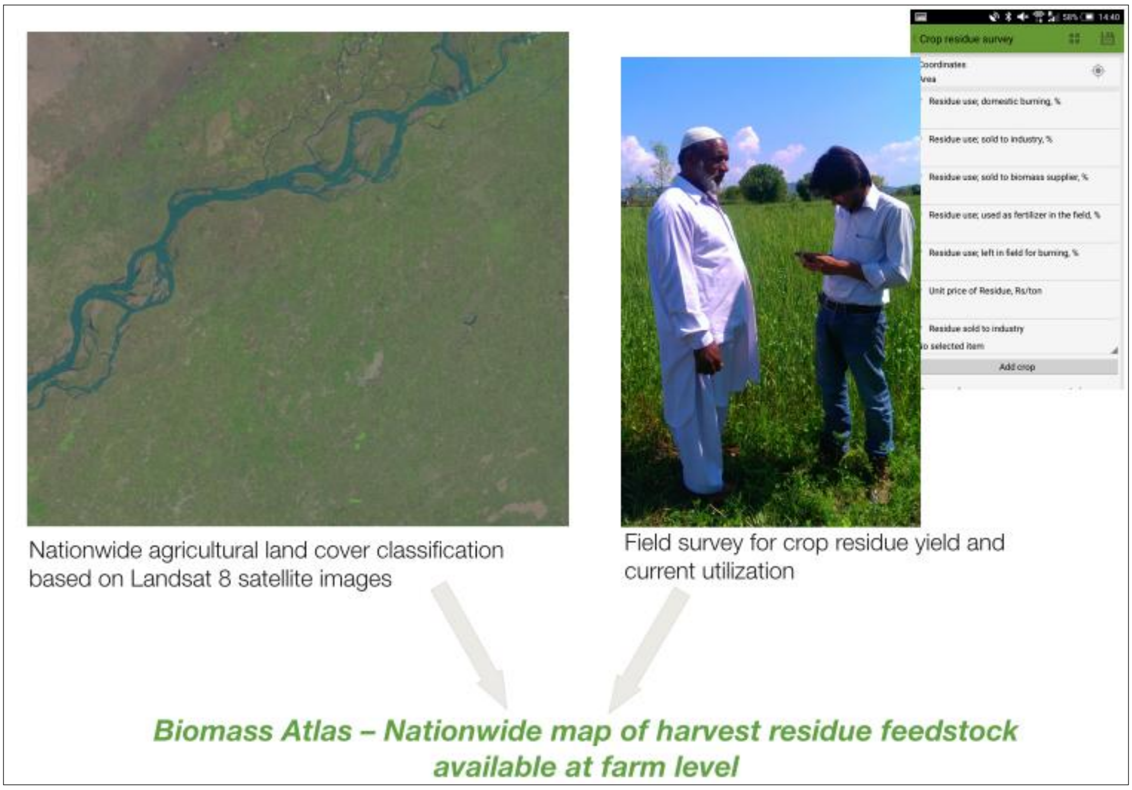

Figure 8: Components of the first atlas, the harvest residue feedstock available at farm level

We used the field survey data to derive the harvest residue feedstock map from the land cover classification map. The results for the survey were aggregated at district level. For each crop being analyzed (wheat, rice, sugarcane, maize), the crop yield and current utilization patterns for the harvest residues were aggregated from single responses to district level average values as well as

[9] *http://wiki.openstreetmap.org/wiki/Downloading_data*
[10] *https://www.humanitarianresponse.info/en/operations/pakistan/dataset/pakistan-roads*
[11] *https://www.humanitarianresponse.info/en/operations/pakistan/datasets*
[12] *https://play.google.com/store/apps/details?id=menion.android.locus&hl=en*

their standard deviation and min-max values. The utilization patterns modeling used the answers to these survey questions:

- Would you agree to a cooperative harvesting, baling and transporting arrangement?
- Residue use, left in field for burning, %
- Residue use, sold to biomass supplier, %
- Residue use, sold to industry, %
- Residue use, used as fertilizer in the field, %

That means that residues used as animal fodder and as domestic fuels were not considered to be available for industrial power generation, but all the rest of the harvest residues was. However, this was also conditional on the farmer's attitude towards joining a commercial feedstock supply chain. If the farmer was not willing to join, none of the harvest residue was considered to be available.

Finally, the crop yield values from the survey responses were converted to different harvest residues based on residue-to-crop-ratios[13] (Table 8)

Table 8: The residue-to-crop ratio (RCR) used in the analysis

Crop	Residue	RCR		
		Average	Min	Max
Wheat	Straw	1.00	0.50	1.30
Cotton	Stalks	3.40	2.76	4.25
Rice	Straw	1.00	0.42	1.30
Rice	Husks	0.20	0.15	0.36
Maize	Stalks	1.25	1.00	2.25
Maize	Cobs	0.33	0.20	0.86
Maize	Shells (husk)	0.22	0.20	0.30
Sugarcane	Trash	0.12	0.10	0.20
Sugarcane	Bagasse	0.30	0.26	0.32

The result is a map for each of the harvest residue listed in Table 8 showing the amount of harvest residue available at the farms (Figure 9). At the finest level of detail, these maps are at 30x30 m resolution, but for usability they are further aggregated to 990x990 m resolution, which will reduce the file size to a usable level.

[13] *Source: GIZ 2013, Report on Biomass Potential Resource Assessment and Feedstock Preparation, prepared by the Alternative Energy Solution Providers (Pakistan).*

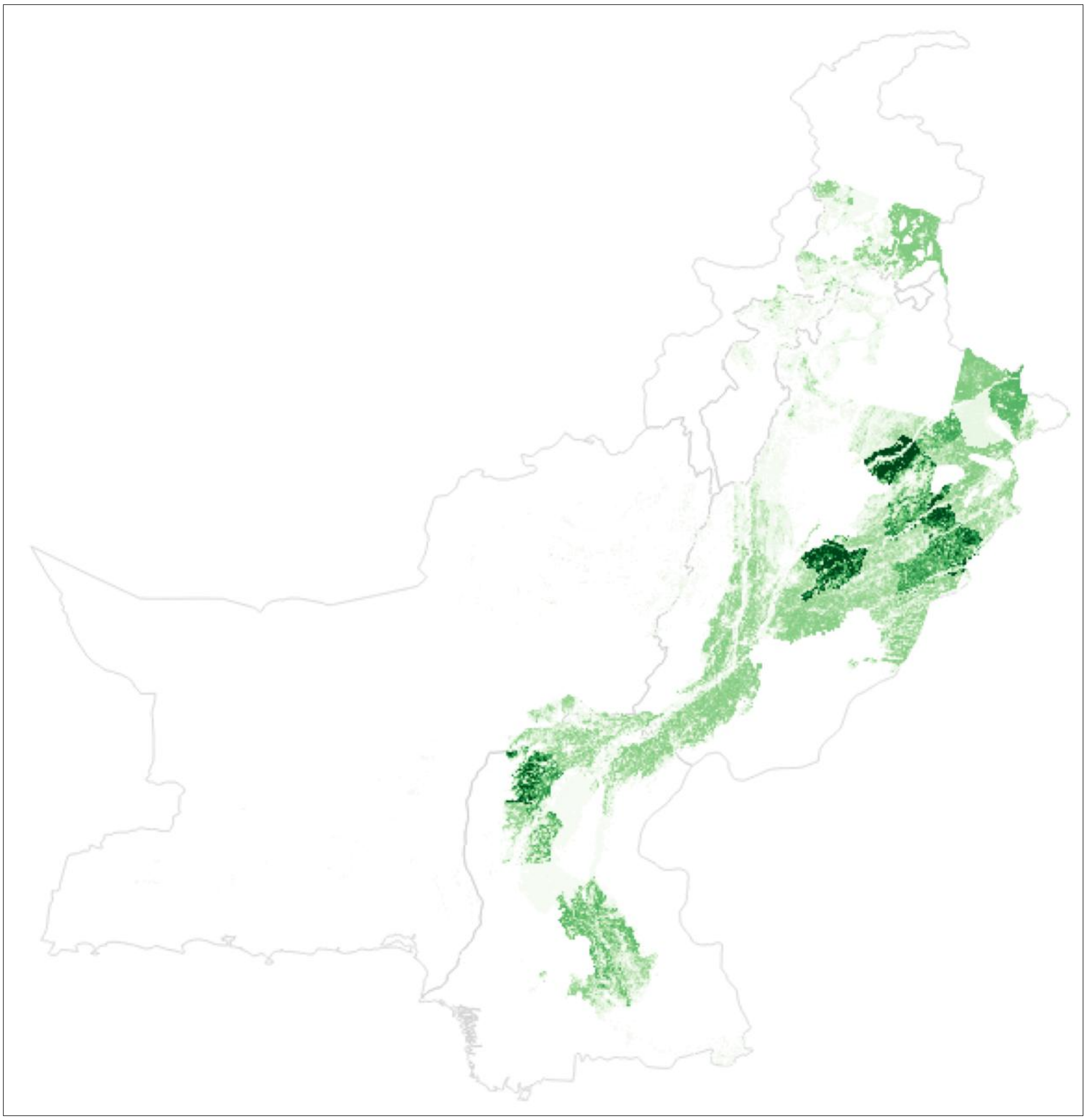

Figure 9: Draft total harvest residue feedstock estimate map
(based on the classification for the late Kharif season dataset. Darker green implies more residues available. The final maps will be based on all seasonal datasets)

The second step of the data analysis and atlas creation is illustrated in Figure 10.

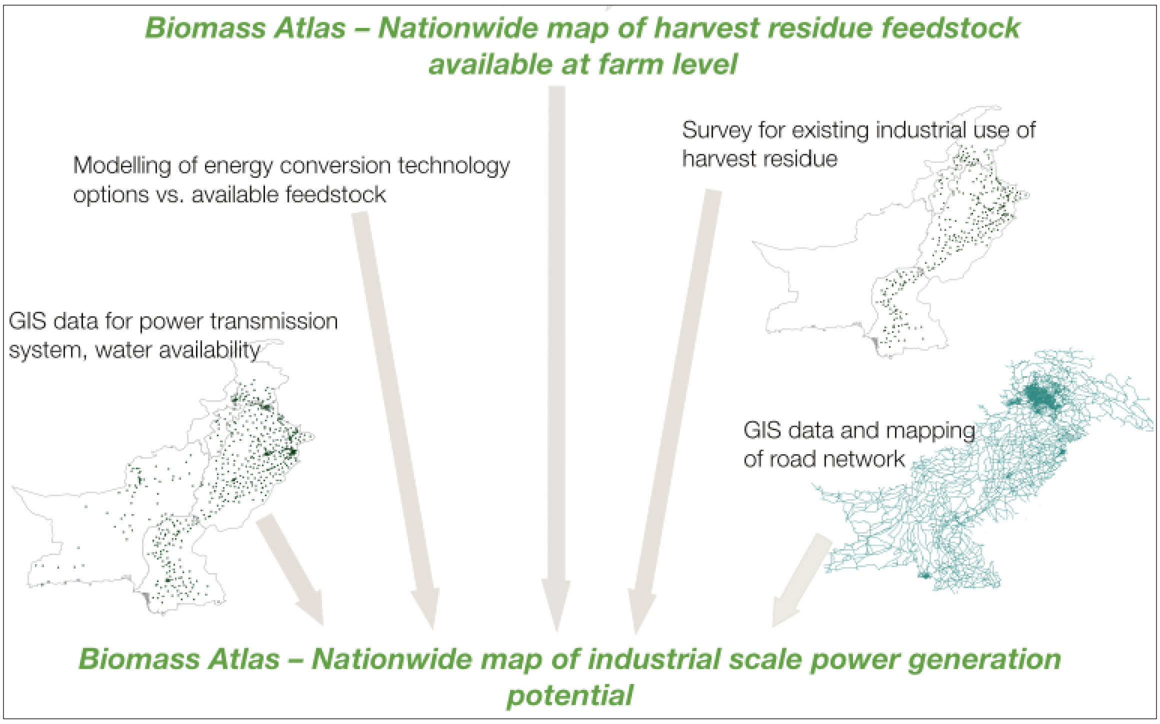

Figure 10: Steps to create the industrial scale power generation potential atlas

The output of the second step is a series of maps highlighting areas of high potential for industrial scale power generation. Each map is for one specific energy conversion technology and plant size. The maps are created based on a concept of a suitability index: the higher the index value, the higher the potential of the site for industrial power generation with the given technology.

The set of analyzed technologies and plant sizes is:

- Horizontal grate combustion steam boiler + steam turbine; 3 MW, 8 MW
- Incline grate combustion steam boiler + steam turbine; 3 MW, 8 MW
- Bubbling Fluidized Bed Combustion steam boiler + steam turbine; 8 MW, 15 MW
- Circulating Fluidized Bed Combustion steam boiler + steam turbine; 15 MW
- Gasifier + syngas engine/turbine; 0.5 MW
- Anaerobic digester + biogas engine; 0.5 MW, 1.5 MW

This means that the final output for this second type of maps will consist of 10 suitability index maps.

To derive these maps, we use the harvest residue feedstock maps to model the distance from which the feedstock has to be sourced to the power plant; in order to derive the distance, the applicability of each feedstock for the given technology was graded with a three step grading system; 0 – not suitable, 1 – acceptable, 2 – recommended. The grading matrix used is shown in Table 9.

Table 9: The feedstock suitability matrix for power plant modelling

Type of technology	Horizontal grate combustion steam boiler + steam turbine			Incline grate combustion steam boiler + steam turbine			BFBC(1) steam boiler + steam turbine			CFBC(2) steam boiler + steam turbine			Gasifier + syngas engine/turbine		Anaerobic digester + biogas engine	
Capacity range (MWe)	3	8	15	3	8	15	3	8	≥ 15	3	8	≥ 15	0.5	1.5(4)	0.5	1.5
Crop biomass residues (after harvesting):																
Wheat straw	1	2	1	1	2	1	1	2	2	0	2	2	0	0	1	1
Cotton stalks	2	2	2	2	2	2	2	2	2	1	1	2	2	0	0	0
Rice straw	1	2	1	1	1	1	1	2	2	1	2	2	0	0	1	1
Maize stalks	1	1	0	1	1	0	0	2	2	0	1	2	1	0	1	1
Sugarcane trash	1	1	0	1	1	0	1	2	2	1	1	2	0	0	1	1
Agro-Industrial biomass residues (after crop processing):																
Rice husk	1	1	1	2	2	2	2	2	2	1	2	2	2	0	0	0
Corn cob	2	2	1	2	2	2	2	2	2	1	2	2	2	0	0	0
Bagasse	1	2	2	1	2	2	1	2	2	1	2	2	0	0	1	1
Other biomass residues:																
MSW(3)	0	1	2	1	2	2	1	2	2	1	2	2	0	0	2	2
Cattle manure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2

Remarks:
(1) BFBC = Bubbling fluidized bed combustion
(2) CFBC = Curculating fluidized bed combustion
(3) Only biodegradable fraction of MSW is suitable for digester
(4) For 1.5 MWe systems, use 3 x 0.5 MWe modules

The feedstock sourcing distance-modeling principle is illustrated in Figure 11. The same principle applies also to the other factors used in modeling the site suitability index. First a 990 x 990 m grid is spanned over the whole country. Then for each grid cell (one marked in the figure with "X") the minimum distance from which the total feedstock amount needed to operate the power plant can be sourced is computed using the feedstock map. This is done for the recommended feedstock for the plant that is most abundantly available: the shorter the sourcing distance, the higher the site suitability index value for the grid cell under analysis.

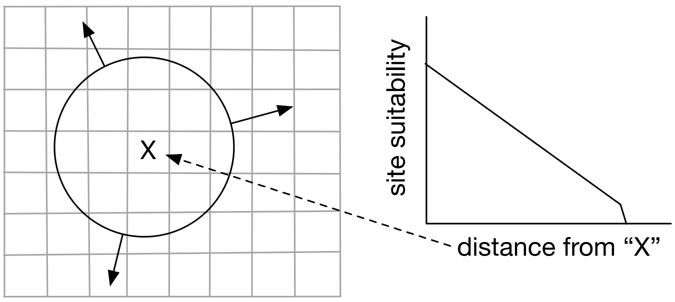

Figure 11: The modeling principle for the different site suitability factors.

However, before computing the site suitability for single fuel availability, the direct, "as-crow-flies" minimum sourcing distance is converted to an approximation of the real sourcing distance with the help of road network density in the area. The road network density, shown in Figure 12, was estimated based on road network data downloaded from the Open Street Map[14] and UNOCHA Pakistan[15] services. In the final version also the road network segments recorded by the project's field survey will be utilized for this purpose.

[14] *http://wiki.openstreetmap.org/wiki/Downloading_data*
[15] *https://www.humanitarianresponse.info/en/operations/pakistan/dataset/pakistan-roads*

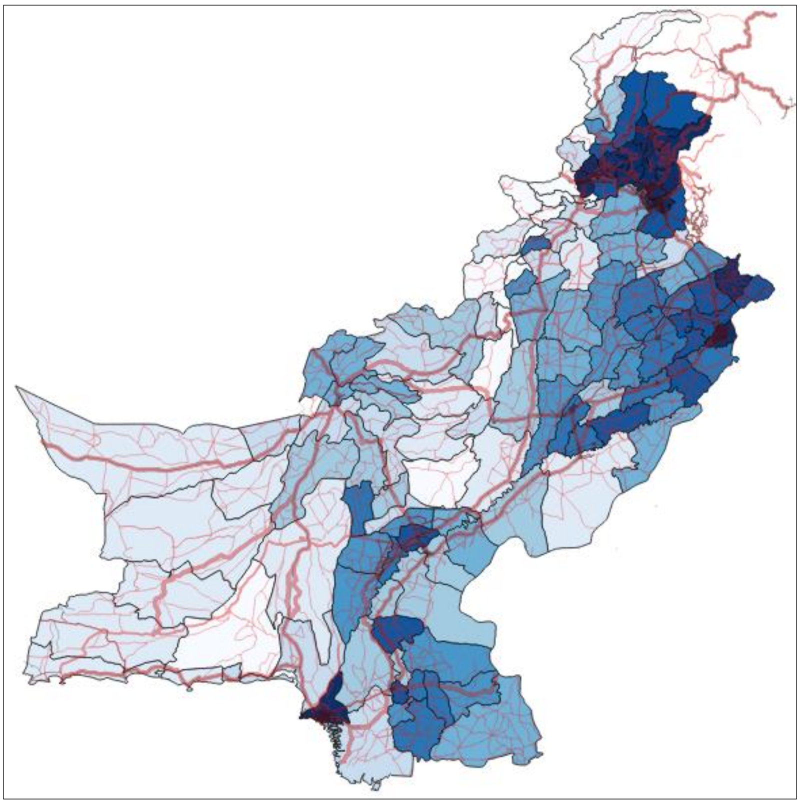

Figure 12: Road network data used, and the derived, district level road network density estimate (Darker blue indicates higher road network density)

The second index, after the single fuel sourcing distance index, to be computed for creating the final site-suitability index, was multi-fuel sourcing index. Again, the feedstock suitability was modeled, but now conditional on the primary feedstock, and its minimum share of the feedstock mix (Table 10). Based on this grading, we computed a multi-fuel sourcing distance index similarly to the single fuel sourcing distance index.

Table 10: Feedstock mix suitability grading, given the primary feedstock and its minimum share (0 – not suitable, 1 – acceptable, 2 – recommended)

Type of technology	Suitable feedstocks to mix with	Horizontal grate combustion steam boiler + steam turbine			Incline grate combustion steam boiler + steam turbine			BFBC(1) steam boiler + steam turbine			CFBC(2) steam boiler + steam turbine			Gasifier + syngas engine/turbine		Anaerobic digester + biogas engine	
Capacity range (MWe)		3	8	15	3	8	15	3	8	≥ 15	3	8	≥ 15	0.5	1.5	0.5	1.5
Crop biomass residues (after harvesting):																	
Wheat straw (>60%)	Cotton stalks Rice straw Maize stalks Sunflower stalks Sugarcane trash	1	2	2	1	2	2	1	2	2	0	2	2	0	0	0	0
Cotton stalks (>60%)	Wheat straw Rice straw Maize stalks Sunflower stalks Sugarcane trash	1	2	2	1	2	2	1	2	2	1	2	2	0	0	0	0
Rice straw (>60%)	Wheat straw Cotton stalks Maize stalks Sunflower stalks Sugarcane trash	1	2	2	1	2	2	1	2	2	0	2	2	0	0	0	0
Maize stalks (>60%)	Wheat straw Cotton stalks Rice straw Sunflower stalks Sugarcane trash	1	2	2	1	2	2	1	2	2	0	2	2	0	0	1	1
Sugarcane trash	With bagasse, but as secondary fuel	1	2	2	1	2	2	1	2	2	0	2	2	0	0	1	1
Agro-Industrial biomass residues (after crop processing):																	
Rice husk (>60%)	Wheat straw Cotton stalks Rice straw Maize stalks Sunflower stalks Sugarcane trash Corn cob Sunflower husk Bagasse	1	2	2	2	2	2	2	2	2	0	2	2	0	0	0	0
Corn cob (>60%)	Wheat straw Cotton stalks Rice straw Maize stalks Sunflower stalks Sugarcane trash Rice husk Sunflower husk Bagasse	2	2	2	2	2	2	1	2	2	0	2	2	0	0	0	0
Bagasse (>60%)	Wheat straw Cotton stalks Rice straw Maize stalks Sunflower stalks Sugarcane trash Lentil stalks/pods Rice husk Corn cob Corn shells Sunflower husk Lentil husk & shells	1	1	2	1	1	2	1	2	2	0	1	2	0	0	1	1
Other biomass residues:																	
MSW(3)	Wheat straw Cotton stalks Rice straw Maize stalks Sunflower stalks Sugarcane trash Lentil stalks/pods Rice husk Corn cob Corn shells Sunflower husk Bagasse Lentil husk & shells	0	2	2	0	2	2	0	2	2	0	2	2	0	0	2	2
Cattle manure	Wheat straw Cotton stalks Rice straw Maize stalks Sunflower stalks Lentil stalks/pods Bagasse Lentil husk & shells	1	1	0	1	1	0	0	1	1	0	1	1	0	0	2	2

Remarks:
(1) BFBC = Bubbling fluidized bed combustion
(2) CFBC = Curculating fluidized bed combustion
(3) Only biodegradable fraction of MSW is suitable for digester

Similar distance-based index was computed for distance to the nearest power transmission network grid station (Figure 13)

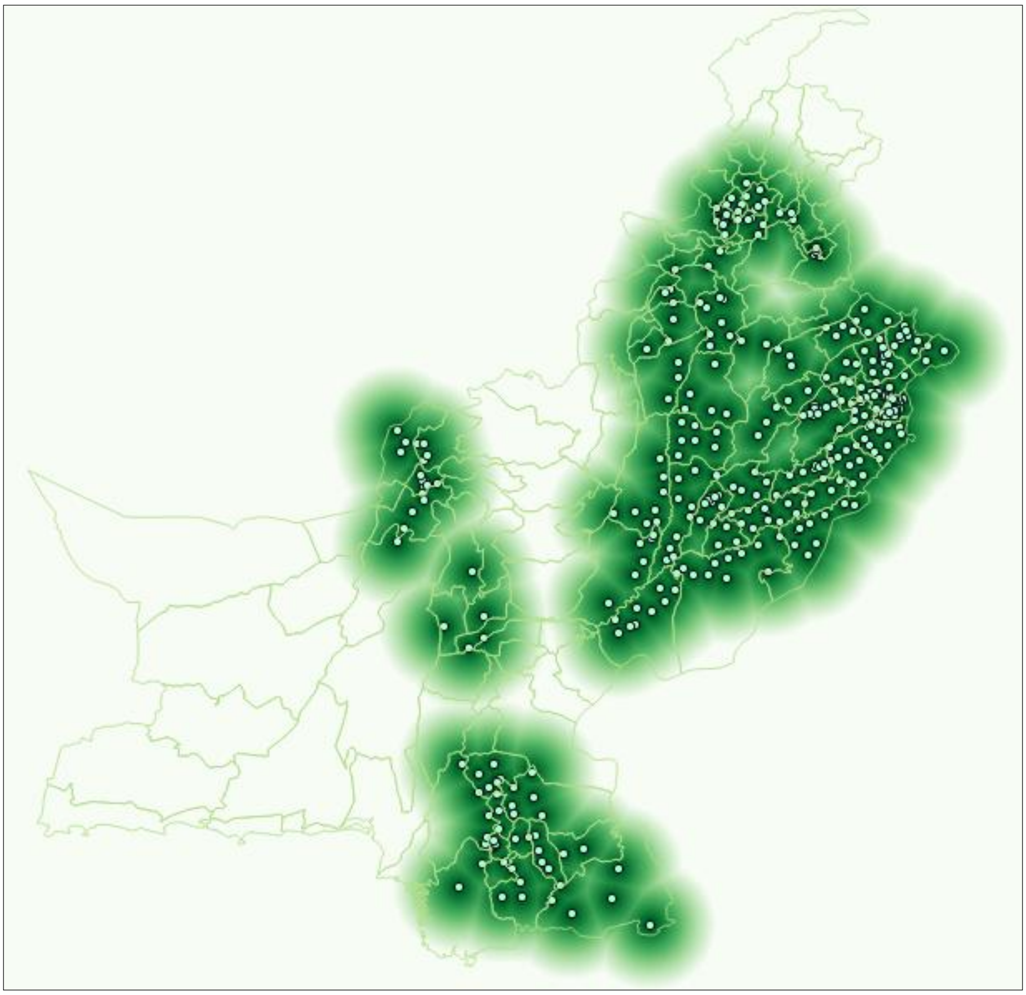

Figure 13: Grid stations, and the computed grid station distance index. (Darker green indicating higher index values, 100 km maximum distance for the grid connection)

Finally the three distance indices (single fuel sourcing, fuel mix sourcing and grid station connection) were combined as a single site-suitability index by weighing the individual indices (0.425 for single fuel, 0.325 for multi-fuel and 0.25 for grid connection). The result is the final site-suitability index for each technology and power plant size combination analyzed. Figure 14 shows an example for a 15 MW bubbling fluidized bed combustion steam boiler power plant.

The site-suitability index is useful for greenfield projects looking for the most potential places for an investment for further analysis. The reverse problem, feasibility analysis for power plant installation on an existing industrial site, can utilize the components of the atlas data that are used to derive the site-suitability index map. How to do this in practice will be the focus of the phase III training workshops.

The existing use of the primary harvest residue feedstock by industrial sites will also be included, to the degree possible by the data available, in the final version of the site-suitability index maps.

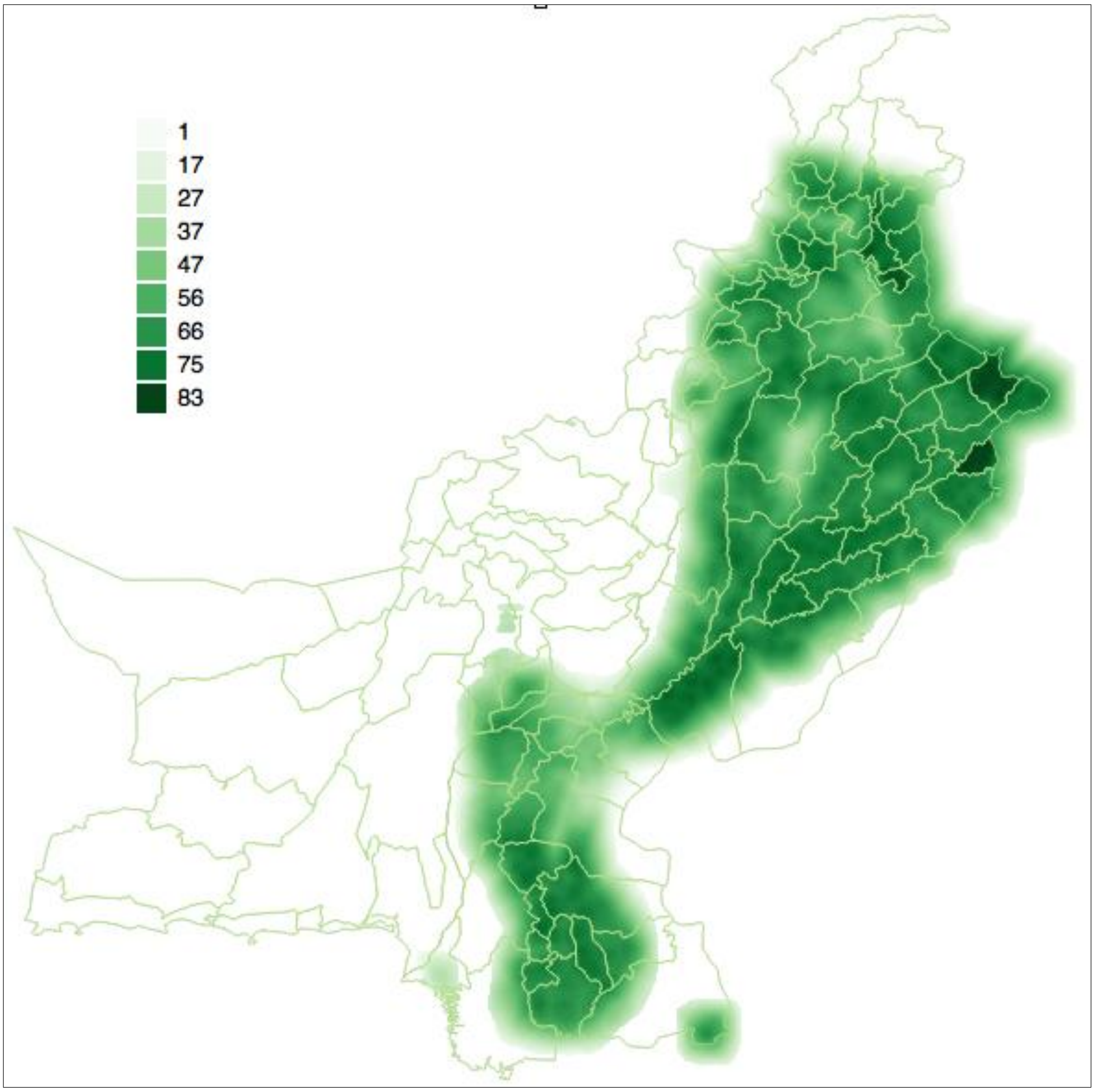

Figure 14: Site-suitability index for 15 MW bubbling fluidized bed combustion based power plant. Index value ranges from 0 (not suitable) to 100 (highly suitable)

7. STAKEHOLDER DATA VALIDATION WORKSHOP

A stakeholder data validation workshop was conducted in Islamabad on 26 November 2015. The event was held at the Serena Hotel Islamabad.

The objective of the workshop was to present the draft Biomass Atlas to the stakeholders for validation. It also aimed at seeking feedback from the stakeholders on the data collected and on the draft Biomass Atlas in order to finalize and produce a high-quality validated Biomass Atlas for Pakistan.

The topics of this multi-stakeholder workshop included the following:

- Progress updates of the Biomass Resource Mapping Project for Pakistan;

- Presentation of the crop biomass survey, including the survey methodology, results and lesson learned;
- Presentation of the industrial biomass survey, including the survey methodology, results and lesson learned;
- Presentation of the draft Biomass Atlas for Pakistan, including the mapping methodology, utilization, updating and key limitations of the Atlas;
- Presentation of the next steps of Biomass Resource Mapping Project for Pakistan.

The Data Validation Workshop was well attended. It attracted a total of 45 participants, excluding the representatives from World Band and AEDB (5 participants), and from the consulting Consortium (12 participants). The participants consisted of government officers, universities and research institutions, potential project developers and international organizations such as GIZ and UNIDO.

The completion report on this workshop is provided in Attachment 7.

8. Revised Work Plan for Phase 3

8.1 Meeting with the WB and AEDB

In order to plan Phase 3 implementation, the Consortium met with the WB (Mr. Anjum Ahmad) and AEDB (Mr. Nafees Ahmad Khan) representatives on 27 November 2015. Mr. Klas Sander (WB) also joined the meeting through a conference call from Washington DC.

The following issues were discussed:

- ***High Resolution Satellite Data:*** NUST will contact SUPARCO for high resolution data.
- ***GAP Analysis:*** Biomass resource potentials will be compared with those provided in previous studies (FAO report, GIZ report, etc.)
- ***Activities of Phase 3:*** The activities of Phase 3 include: (i) Preparation of Phase 2 report (workshop report, revised implementation plan, survey reports) which is expected to be done by the 1st or 2nd week of December; (ii) Finalization of the Biomass Atlas; (iii) Preparation for the dissemination events, and (iv) Preparation and submission of Final Report (will include write-up on the Biomass Atlas (tabular, graphical, and narrative).
- ***Dissemination events:*** The Biomass Atlas will be disseminated in February 2016 (tentatively third week of February). There will be three types of events: (1) Atlas Dissemination Seminar, (2) Atlas Usage Training Workshop and (3) Atlas Maintenance Training Workshop. Mr. Nafees Ahmad Khan suggested to revise the programme and make presentations in three locations (Islamabad, Lahore and Karachi) instead of only one (Islamabad) as originally planned, Mr. Anjum Ahmad informed that he had just received some communication from WB Headquarters that the President of the WB might be visiting Pakistan during the period of the dissemination events. Dr. Jussi Rasinmäki explained that one day per location should be sufficient for the combined Atlas Dissemination Seminar and Atlas Usage Training Workshop as long as the attendees are fluent with IT and GIS. It is planned that the Atlas

Maintenance Training Workshop will take place in Islamabad only while three one-day combined Atlas Dissemination Seminars and Atlas Usage Training Workshops will be organized in Islamabad, Lahore and Karachi. The consortium would like to have all the events within one week. Mr. Anjum Ahmad will inform the Consortium about the final dates for the events. A first glance, Phase 3 Budget shows room to accommodate the two additional events. That will need to be confirmed.

- ***Host for Biomass Atlas:*** A host needs to be identified that will take ownership of the Biomass Atlas and will be responsible for updating it. Mr Qazi Sabir suggested that SUPARCO can host the Atlas even though they haven't shared any data but they do have the required expertise to update it. Dr. Jussi Rasinmäki and Mr Anjum A. are in agreement with Mr Qazi Sabir as long as it can be ensured that SUPARCO will be willing to share the data. It was then suggested that a commercial model should be considered to establish a public-private partnership. AEDB should be the host along with other partners (such as NUST and/or PITCO) that can assist in updating the atlas. Dr. Jussi Rasinmäki was requested to provide the TOR for maintaining/updating the Biomass Atlas so that the level of effort can be estimated for this task. It was also suggested that NUST could contact the Higher Education Commission (HEC)'s Industry University Linkages of Pakistan to seek funding for the updating of the Biomass Atlas and they in turn would make data available for Master or PhD research of students.
- ***Updating of Biomass Atlas:*** The updating of Biomass Atlas would consist of two parts: (i) Field Data Collection (A web portal can be developed for adding updated data. The 2nd approach is that a dedicated field collection activity takes place but that requires funding. The two approaches can be combined); and (ii) Updating the database according the collected data (Training shall provide during the dissemination events).

8.2 Revised Work Plan for Phase 3

Based on the discussions with the WB and AEDB representatives, the Work Plan for Phase 3 of the project was revised. It is presented in the table below:

Revised Work Schedule

No	ACTIVITY	Date Covered: (DD/MM/YY)	Lead	Support		Nov 14	Dec 14	Jan15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15	Jan 16	Feb 16	Mar 16
I	**Phase I**																					
2	Contract Signing	09/11/14																				
3	**Project Inception**																					
4	Inception meeting	01/11 - 26/11/14	FA	Simosol, PITCO																		
5	Compile Inception Report	27/11 - 04/12/14	FA	Simosol, PITCO																		
6	Deliver Inception Report to the WB and the Client	05/12/14	FA																			
7	Data Source Identification	19/11 - 31/12/14	PITCO	FA, Simosol																		
8	Team Building	01/11 - 26/11/14	FA	Simosol, PITCO																		
9	Implementation planning	27/11/14 - 02/03/15	FA	Simosol, PITCO																		
10	Submission of Implementation Plan (IP)	03/03/15	FA	Simosol, PITCO, LSC																		
II	**Phase II**																					
11	WB reviews and approves IP and budget for Phase II	09/03/15	WB																			
12	WB and FA sign Contract Amendment	12/03/15	WB	FA																		
13	FA signs contract with NUST	18/03/15	FA, NUST	Simosol, PITCO																		
14	**Prepare for remote data collection**																					
15	Gather available land cover and land use classifications	15/02 - 31/03/15	PITCO	Simosol, LSC																		
16	Prepare for field data collection	15/02 - 31/03/15	Simosol, FA	PITCO, LSC																		
17	Image analysis of the time series[16]	01/03 - 30/04/15	Simosol	VTT																		

[16] *Only applicable if activity 15 "Gather available land cover and land use classification" fails to secure access to the available data on land cover and land use classifications of SUPARCO.*

No	ACTIVITY	Date Covered: (DD/MM/YY)	Lead	Support		Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15	Jan 16	Feb 16	Mar 16
18	**Conduct training and on-site data collection**																					
19	Prepare for training workshop on data collection	10/03 - 20/03/15	Consortium	LSC																		
20	Conduct training workshop on data collection (Trainer's Training, Field Surveyor Training)	07/04 - 9/04/15	Consortium	LSC																		
21	Conduct GIS data acquisition of other driving components	13/04 - 30/06/15	PITCO																			
22	Conduct field data collection of industrial biomass residues / MSW	13/04 - 10/11/15	PITCO																			
23	Conduct field data collection of crop biomass residues	13/04 - 14/10/15	NUST, PITCO	LSC																		
24	Data analysis and mapping	02/03 - 20/11/15	Simosol, VTT	FA, PITCO																		
25	Submission of comprehensive database necessary for biomass resource mapping, including raw data files	26/11/15	Simosol	FA, PITCO														★				
26	Submission of draft Biomass Atlas	26/11/15	Simosol	FA, PITCO														★				
27	Stakeholder validation workshop	26/11/15	Consortium	LSC														★				
28	Report on Phase 2 implementation and Revise Implementation Plan for Phase 3 based on feedback from the workshop	23/12/15	FA	Simosol, PITCO															★			
29	**Phase III**																					
30	Final analysis and mapping	01/12/15 - 31/01/16	Simosol, VTT	FA, PITCO																		
31	Production of final Biomass Atlas and associated GIS files/datasets	01/12/15 - 31/01/16	Simosol	FA, PITCO																		
32	Prepare for dissemination workshop and training	02/01 - 31/01/16	Consortium	LSC																		
33	Execute seminars and training workshops	15-19/2/16	Consortium																			
34	Submission of Final Biomass Atlas and database	15/3/16	Consortium																			★

LEGEND:	**LSC**	- **Local Sub-Contractors**	▲	- **Milestone**	★	- **Deliverables**		**- Home Work**		**- Field Work**

9. Conclusions and Recommendations

9.1 Conclusions

Remote Data Collection and Analysis:

The initial concept for the crop level land use mapping using the freely available Landsat8 images was validated during phase II. However it is also evident that the relatively low spatial resolution of 30x30 m can not be fully compensated by using multiple acquisition times over the year, as seasonal cloudiness reduces availability of good quality images. However, if a land use classification based on higher spatial resolution imagery will become available, the workflow to update the atlas after Phase 3 is readily available, and the Atlas Maintenance Training Workshop will provide training on how this is done in practice.

During Phase 3 the land use classification will be finalized by improving the radiometric calibration of the image time-series and basing the classification on the combination of the single time season crop classification into a single two-season crop classification.

Preparation for Field Survey and Data Collection:

A training workshop on field survey and data collection of crop biomass residues in Pakistan was conducted in Islamabad on 7-9 April 2015. It provided a hands-on training to the field surveyors from NUST and two other universities for conducting surveys using 3G smartphones and Android applications. A smartphone based field survey questionnaire using the MHG Mobile app was developed for training purpose.

Crop Biomass Survey:

The crop survey activity was conducted in collaboration with universities and agriculture departments in different regions of Pakistan using digital survey tools. The questionnaire was designed to explore the net availability of biomass or crop residue for power production excluding utilization of biomass as feed or at domestic and industrial level. The coordination among universities, agriculture departments and NUST as focal point has helped successfully complete the crop survey in Pakistan. The farmers were not aware of the importance of crop residue as energy source. The survey activity has created a hope to the farmers, and biomass is being now viewed as a resource in the surveyed community.

Industrial Biomass Survey:

The industrial survey conducted by PITCO revealed that for almost all of biomass based power plants, rice husk is either the primary or the only biomass residue used for power generation. Furthermore, the survey of rice mills showed that large amounts of rice husk are being consumed by the brick industry, which is a known inefficient consumer of biomass residues in Pakistan. This is particularly true for the Kamber Shahdad Kot and Larkano districts of Sindh.

The sugar sector of Pakistan is increasingly moving towards an efficient use of bagasse through adoption of high pressure cogeneration systems. Therefore, it is envisaged that in the future, all of the bagasse generated will be consumed by the sugar mills themselves and there will be no surplus availability for use by other consumers.

The solid waste management companies in Pakistan show increased awareness of the benefits of managed landfill sites. Most of them have plans to establish a managed landfill site in the near future, with some of them having plans for power generation using the gas captured from the landfills.

Cement plants, which historically consumed large quantities of biomass, have stopped using biomass due to the sharp fall in coal prices in the recent years. This will continue to be the case as coal prices are not expected to rise significantly in the foreseeable future.

Of all the industrial biomass residues surveyed by PITCO, rice husk holds the greatest potential for power generation.

Data Analysis and Development of a Draft Biomass Atlas:

The Biomass Atlas will contain two sections: the first one related to feedstock availability at farm level and the second one related to site-suitability. They are based on a set of modeling assumptions in addition to the land use classification and collected survey data. They are also subject to the inherent uncertainty in the crop yield levels and the field survey results. This means that the users of the Atlas must be aware of these assumptions and the degree of uncertainty. Delivering those together with the Atlas is essential for their proper use. This will also be highlighted in the Training Workshops to be arranged at the end of Phase 3. Another aspect to be focused on in the Training Workshops is how to utilize the atlas data for feasibility analysis for brownfield projects. That is something that is by definition an analysis focusing on a single location, and doesn't thus lend itself very well to the atlas concept. However, the data behind the atlas also fully support this kind of analysis.

Stakeholder Validation Workshop:

A stakeholder data validation workshop was conducted in Islamabad on 26 November 2015 to present the draft Biomass Atlas to the stakeholders for validation and verification. The feedback from the stakeholders was received. They will be incorporated in the final processing of the datasets and production of the final Biomass Atlas for Pakistan.

Phase 3 Work Plan Revision:

The Work Plan for Phase 3 of the project was revised based on the participants' feedback during the Data Validation Workshop and on the discussions with the WB and AEDB representatives on 27 November 2015. The production of final Biomass Atlas and associated GIS files/datasets is planned to be completed by the end of January 2016. Then, the Atlas Dissemination Seminars and Training Workshops will be conducted from 15 to 19 February 2016, and the Final Report will be submitted to the WB/AEDB by 15 March 2016.

9.2 Recommendations

It is important to take a decision on who will take over the Final Biomass Atlas and be responsible for updating it. This decision should be taken as soon as possible in order for the Consortium to appropriately plan and prepare the Atlas Maintenance Training Workshop of February 2016.

The participants in the Biomass Atlas Usage and Maintenance Training Workshops should be carefully selected to assure the success of these trainings. The attendees of these training workshops should be fluent with IT and GIS.

10. ATTACHMENTS

Attachment 1: Crop biomass survey form
Attachment 2: Report on training workshop on field survey and data collection
Attachment 3: Reports on training workshops for other participating universities
Attachment 4: Report on M&E of crop biomass survey
Attachment 5: Chronology of crop biomass survey and data collection
Attachment 6: Report on industrial biomass survey
Attachment 7: Report on Data Validation Workshop