**JECAM SAR Inter-Comparison Experiment**

**Component 1: Crop Type Identification & Mapping**

**Activity 1: Applying Operational SAR and Optical Classification Methodologies to Multiple Regions**

***1a. Applying Agriculture and Agri-Food Canada (AAFC) Earth Observation Crop Inventory Method to other JECAM Sites***

The AAFC Crop Inventory SAR and optical classification methodology was developed through intensive research (McNairn et al., 2009), and through ongoing application and adaptation in an operational environment. The Earth Observation (EO) group has produced an annual Canada-wide inventory of crops since 2011 and for the Canadian Prairie Provinces since 2009. The overall inventory covers the agriculture extent of Canada, a diverse area spanning over 5000 km coast to coast, with over 50 crop types classified and 11 general land cover types. The crop class overall accuracies range by province from 82% up to 95% (2016).

The method follows a hierarchical decision tree variant of C5 (See5, Quinlan, 1993) utilizing stacks of raster satellite data (e.g. Landsat 8 (bands 2 to 7 plus the cloud mask), and SAR data (Radarsat-2 OR Sentinel 1)), and vector training data polygons derived from field-surveys or high-resolution image derived reference data.

**Activity parameters:**

In this activity we will apply the AAFC Crop Inventory SAR and optical classification methodology to other JECAM sites that are interested and meet the minimum data requirements. The other sites do not have to currently employ an operational SAR and optical, or SAR only classification methodology to participate.

The class types will be crops only (other land cover classes will be masked) and will focus on target crops (e.g. wheat, maize, soya beans), which will be determined depending upon the participants. Specific group training and validation datasets will be selected from the in situ reference data provided and utilized in this format for all comparative activities for consistency.

The only responsibility of JECAM partners for this activity is to provide in situ reference data and any extra EO data to AAFC. AAFC will obtain and pre-process the publically available EO data such as Landsat, Sentinel-1 and RADARSAT-2 accessible for those interested sites.

**Consideration for participation:**

| **MINIMUM DATA REQUIREMENTS TO PARTICIPATE** | | | **OTHER DATA PREFERENCES (Minimums must be met to participate)** |
|---|---|---|---|
| **Area of Interest (AOI)** | Minimum JECAM site (10 x 10 km) | | 25 x 25 km JECAM site; within same day satellite collection |
| **Year of Interest** | 2015 | | One or more years (2015, 2016, 2017, 2018, 2019) |
| **SAR Imagery** | 2 dual-pol C-band images | | 3 or more C-band dual- or quad-pol |

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| | | | images |
| **Timing for SAR Image Acquisition** | Timing: 1 image close to maturity (e.g. in Canada close to maturity date is in August) | | Timing: Spread throughout the growing season for the particular site (e.g. start of season, peak season, grain filling, end of season) **AT least 1 close to maturity** |
| **Optical Imagery** | 3 cloud 'free' Landsat 8 images | | As many cloud 'free' Landsat images as possible;<br>Other mid to high resolution optical imagery |
| **Timing for Optical Image Acquisition** | Timing: Spread throughout the growing season | | Timing: Spread throughout the growing season |
| **Field-data Minimum Requirements** | • Whole field-size reference data (not within field plots)<br>• Well-outlined class definition and if classes fall under a hierarchy an indication of hierarchical structure (see JECAM Guidelines for Cropland and Crop Type Definition and Field Data Collection) for details.<br>• Points of reference are proportional to the reality of the landscape (e.g. common classes have more reference samples while less common classes have less reference samples).<br>• In situ data are well dispersed throughout the AOI<br>• Data files: GPS waypoints file with field boundaries; georeferenced polygon files | | Well-described polygon file |

***1b. Applying JECAM Member Sites' SAR and Optical, OR SAR only (single frequency) Classification Methodologies to Multiple Regions***

Other JECAM partners may currently utilize classification methodologies employing SAR and optical, or SAR only (single frequency) imagery as input. In the optical-only comparison, Waldner et al. (2016) showed that site effects outweigh method effects when utilizing optical only data and five different JECAM site crop classification methodologies. Similarly, it is important to test other developed SAR and optical classification strategies in an effort to develop a suite of best practice approaches that can be applied depending on region, data availability and processing capability of JECAM partners.

This portion of Activity 1 will be similar to the optical-only comparison in that participants will apply their own methodology on other sites' data. Traditional accuracy measures such as confusion matrices, errors of commission and omission, and overall accuracy will be assessed and statistical comparisons (e.g. McNemar's Test, F-score, etc.) will be applied to the overall accuracies determined for each method at each site. A suite of findings will be disclosed to other JECAM partners who may not currently employ a SAR-based classification method or who are looking to develop a country-wide or regional operational crop inventory.

**Participation requirements:**

JECAM partners interested in utilizing their existing method(s) of classification should be willing to take unprocessed EO data and in situ reference data to utilize with their SAR and optical or SAR only (single frequency) classification methods. AAFC will offer the preprocessed data that was used in Activity 1a to those partners who employ similar processing levels and can use the datasets. The JECAM partners participating in Activity 1b will also need to maintain measurable similarities to other sites conducting the same activity. For example, all reference data will be split into fixed training and validation groups, and will be used as such by all partners to be able to statistically compare the accuracies of the different methods at a later date.

Participants will also be asked to keep the spirit of the JECAM partnership in mind in our attempt to reach a suite of transferrable methods by utilizing realistic data sets (e.g. operational minimums) that potentially could be obtained by all partners country-wide, or over large regions, or repeatedly year to year. Should a JECAM partner be interested in trying a more robust application of their method with additional non-operational data (e.g. adding very high resolution imagery), that portion of the activity would be secondary to the goal of comparing the operational methods.

Other JECAM sites that do not currently employ operational SAR-based classification methodologies may also provide their existing data (e.g. EO imagery, and in situ reference data) to these partners, if they meet the minimum data requirements. This participation may help inform their future focus for operational SAR-based crop assessment and monitoring.

For Activities 1a and 1b, if a JECAM partner site does not currently have in situ reference data or SAR data, but plans to acquire the minimums for these activities in the upcoming years, we will look at the utility of continuing the activities and adding additional sites.

**Activity 2. Reducing the Impact of Cloud Cover on Operational Crop Inventories**

Waldner et al. (2016) found "data availability in areas with persistent cloud cover might be too scarce to ensure a proper temporal feature extraction, which would in turn bring down the classification accuracy". Many other studies have shown that a combined optical and SAR based classification approach often improves on overall accuracies and thematic mapping results over using one or the other type of imagery alone (Blaes et al., 2005, McNairn et al., 2009, Fontenelli et al., 2014, Forkuor et al., 2014). In an operational context it is often difficult to acquire blanket coverage of SAR imagery and therefore it becomes important to determine at what time in the season is it best to acquire the associated SAR images? This will ensure the maximum impact of the SAR imagery while maintaining a cost-effective acquisition strategy.

This particular activity has been carried out for three sites (Canada Red River and Canada Casselman, and USA Michigan) where Landsat 8 data were acquired at key points during the growing season (e.g. start of season, peak season, grain filling, end of season). A minimum of two dual polarization SAR C-band data (either RADARSAT-2 or Sentinel-1) were acquired which corresponded to the Landsat dates. For each site for each date of Landsat imagery, cloud-cover and configuration were randomly synthesized from 1 to 100% of the image. To determine the overall contribution of the corresponding SAR image to the overall classification accuracies, multiple iterations of the AAFC crop inventory classification methodology were run to determine how accuracy changed with changing cloud cover, and the importance of seasonal timing for the contributing SAR imagery. It was found at these three sites, that SAR acquired during the peak or grain filling periods had the greatest impact on the overall classification accuracies when the optical imagery had high cloud cover during the coincident periods.

The purpose of Activity 2 is to expand to other JECAM sites and see how regional differences may change the acquisition date importance of the SAR imagery.

**Activity parameters:**

If a JECAM partner site has met the minimum requirements for Activity 1a then the site can participate in this activity. There are no other requirements.

**Activity 3 and 4. Multi-frequency SAR imagery for Crop Type Mapping *AND* Compact polarimetry and/or polarimetric decomposition variables for Crop Type Mapping.**

Other uses of SAR imagery and derived variables in crop assessment and monitoring include the addition of multiple frequencies (e.g. C-, L- and X- bands) in one classifier (McNairn et al., 2009, Shang et al., 2009); or the use of compact polarimetric variables (McNairn et al., 2009, Charbonneau et al., 2010), or the use of polarimetric decomposition variables such as those derived from Cloude-Pottier, Freeman-Durden and/or other decompositions (McNairn et al., 2009, Jiao et al., 2014). These studies have shown that the addition of these diverse variables can negate the need for optical imagery in a crop classification. A SAR-only option becomes more viable as satellite missions come online such as the RADARSAT Constellation Mission (expected launch 2018) with temporally continuous, large region coverage.

These activities will be developed to include these types of SAR imagery and derived variables in an operational context. EO data acquisition and field surveys will be planned. Further details and directions will be determined through a review of the existing literature, and as JECAM partner interest, and participation is established.

**Major milestones for Component 1**

| No. | Milestones | Timing | Owner | Objectives | Deliverables |
|---|---|---|---|---|---|
| 1 | Project Scope | Q2 2017 | AAFC | Development of project plan and tentative activities | Project Plan |
| 2 | Determining Participants for Activities 1a, 1b and 2. | Q2 2017 | AAFC | Contacting JECAM partners to confirm interest and capability. Requesting in situ reference data and | List of participating partners for Activities 1a, 1b, and 2. |

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| | | | | additional EO data from those interested. | |
| 3 | Activity 1a & Activity 2: Preprocessing of EO and in situ reference data for participants | Q2 & Q3 2017 | AAFC | Obtaining and preprocessing EO imagery; creating field polygons (as required) from provided in situ reference data | Sets of preprocessed SAR and optical imagery with vector reference data |
| 4 | Activity 1b: Preprocessing | Q3 2017 | JECAM partner sites | Coordinating with participants on collection of available imagery and field data | Sets of preprocessed SAR and optical imagery with vector reference data |
| 5 | Activity 1a & Activity 2: Application of AAFC Crop Inventory methodology | Q3 & Q4 2017 | AAFC | Iterations of the AAFC Crop Inventory method on the data provided by sites that meet the minimum requirements for both activities | Activity 1a Results |
| 6 | Determining Participants for Activity 3 | Q4 2017 | AAFC | RE-contacting JECAM partners to confirm interest and capability. | List of participants for Activity 3 |
| 7 | Activity 1b: Application of Methodologies | Q4 2017 | JECAM partner sites | Iterations of the JECAM sites SAR and optical OR SAR only methodologies on the data provided by sites that meet the minimum requirements | Activity 1b Results |
| 8 | Activity 1a & 2: Publication(s) | Q4 2017 & Q1 2018 | AAFC | Publication of results in peer-reviewed Journals and presentations at International Conferences | Paper(s) and/or conference presentation(s) |
| 9 | Annual Report | Q1 2018 | AAFC | Providing end of first year report to Canadian Space Agency (CSA) and JECAM partners | Annual Report #1 |
| 10 | Activity 3: Literature Review and Activity Plan | Q1 2018 | AAFC & JECAM Partner sites | Review of literature and development of Activity plan | Literature Review and Activity Plan |
| 11 | Activities 1a & 1b: Statistical Comparison | Q1 & Q2 2018 | AAFC & JECAM Partner sites | Statistical comparison of the results of the SAR & optical and SAR only methods applied on the different regions | Comparison Results |
| 12 | Activity 3: Pre-processing | Q2 & Q3 2018 | AAFC & JECAM Partner sites | Obtaining and preprocessing EO imagery; creating field polygons (as required) | Sets of preprocessed SAR and optical imagery with vector reference data |

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| | | | | from provided field data | |
| 13 | Activity 1a & 1b: Publication(s) | Q3 2018 | AAFC & JECAM Partner sites | Publication of results in peer-reviewed Journals and presentations at International Conferences | Paper(s) and/or conference presentation(s) |
| 14 | Determining Participants for Activity 4 | Q4 2018 | AAFC | Contacting JECAM partners to confirm interest and capability. Requesting field data and additional EO data from those interested. | List of participants for Activity 4 |
| 15 | Activity 3: Application of Methodologies | Q4 2018 & Q1 2019 | AAFC & JECAM Partner sites | Iterations of the Multi-Frequency SAR only methodologies on the data provided by sites that meet the minimum requirements | Activity 3 Results |
| 16 | Annual Report | Q1 2019 | AAFC | Providing end of second year report to CSA and JECAM partners | Annual Report #2 |
| 17 | Activity 4: Literature Review and Activity Plan | Q1 2019 | AAFC & JECAM Partner sites | Review of literature and development of Activity plan | Literature Review & Activity Plan |
| 18 | Activity 3: Publication(s) | Q1 & Q2 2019 | AAFC & JECAM Partner sites | Publication of results in peer-reviewed Journals and presentations at International Conferences | Paper(s) and/or conference presentation(s) |
| 19 | Activity 4: Pre-processing | Q2 & Q3 2019 | AAFC & JECAM Partner sites | Obtaining and preprocessing EO imagery; preparing for field season (if required), creating field polygons (as required) from provided field data | Sets of preprocessed SAR and optical imagery with vector reference data |
| 20 | Activity 4: Application of Methodologies | Q4 2019 & Q1 2020 | AAFC & Interested JECAM Sites | Iterations of the Multi-Frequency SAR OR SAR only methodologies on the data provided by sites that meet the minimum requirements | Activity 4 Results |
| 21 | Annual Report | Q1 2020 | AAFC | Providing end of 3rd year report to Canadian Space Agency (CSA) and JECAM partners | Annual Report #3 |
| 22 | Activity 4: Publication(s) | Q1 & Q2 2020 | AAFC & Interested | Publication of results in peer-reviewed Journals | Paper(s) and/or conference |

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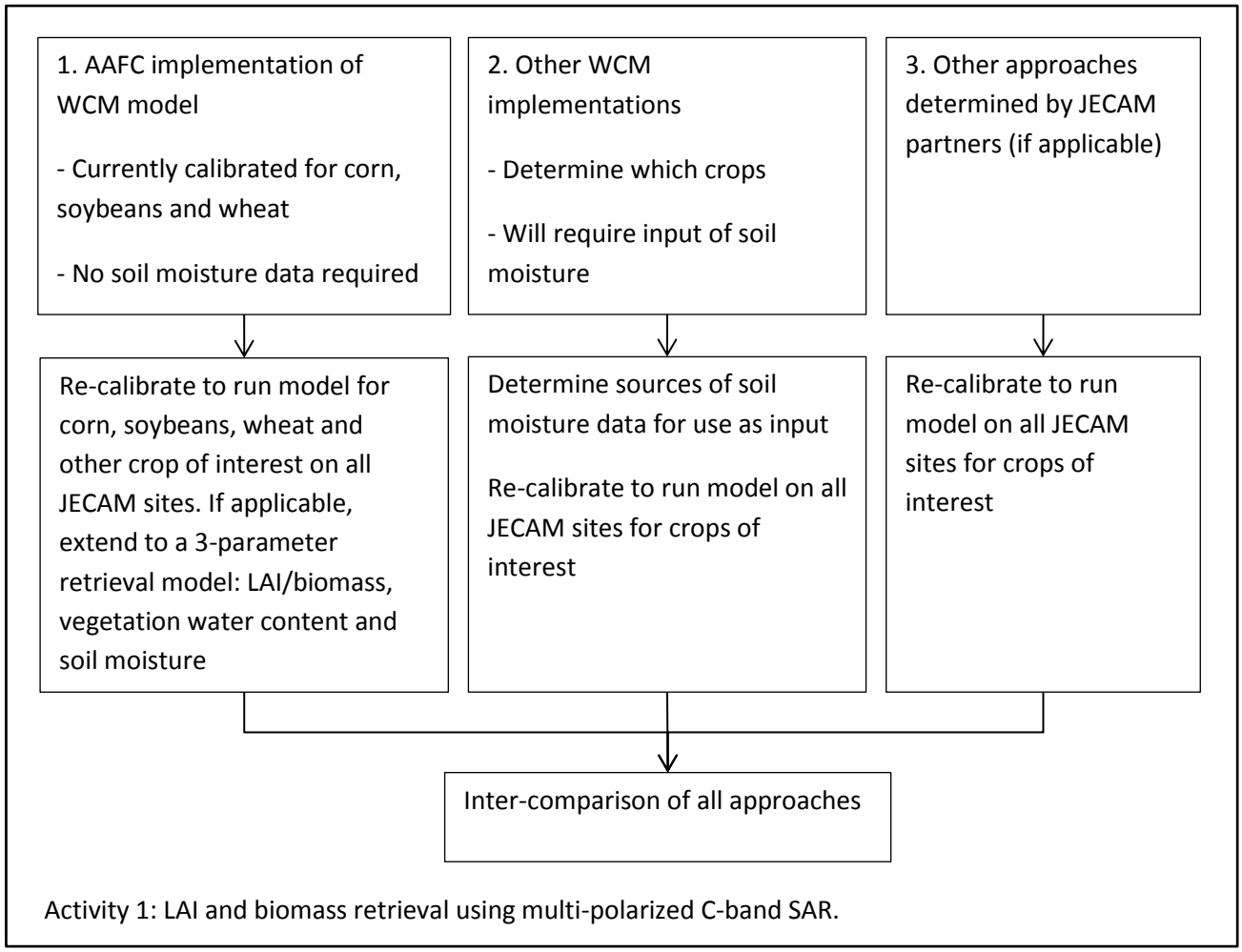
| | | | JECAM Sites | and presentations at International Conferences | presentation(s) |
| 23 | Capacity Building Conference / JECAM Meeting | Q3 or Q4 2020 | AAFC | JECAM Conference and 2 Day SAR Workshop | Conference materials and method recommendations |
| 24 | Final Report | Q4 2020 | AAFC | Final report to CSA and JECAM partners | Final Report |

**Component 2: LAI & Biomass**

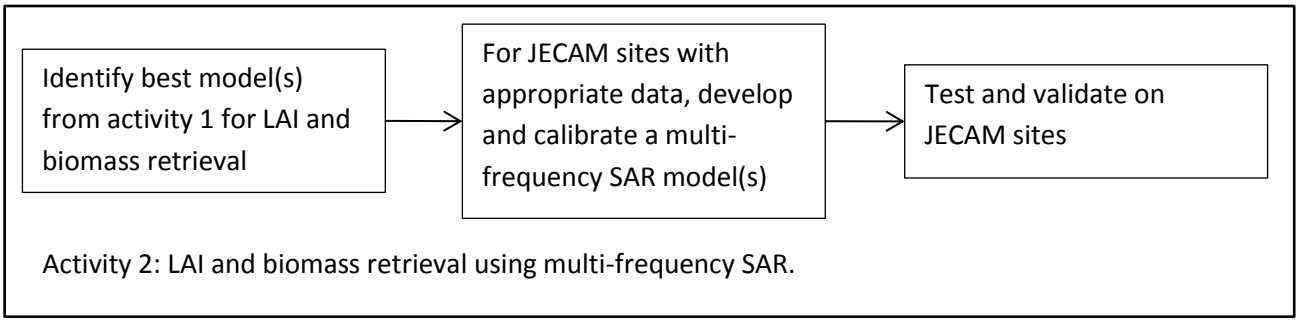
The Water Cloud Model (WCM) has been tested successfully for the retrieval of Leaf Area Index (LAI) and biomass estimation over the Red River JECAM site as well as the Iowa SMEX02 experimental site (Hosseini et al., 2015 and Hosseini and McNairn, 2017). This model has been parameterized for corn, soybeans and wheat. For this SAR inter-comparison project we would aim to recalibrate and improve the WCM model using data from other JECAM sites and expand it to other economically crop types and compare the WCM approach with the methods used by other JECAM participants. Given that, we would implement the following activities within this project:

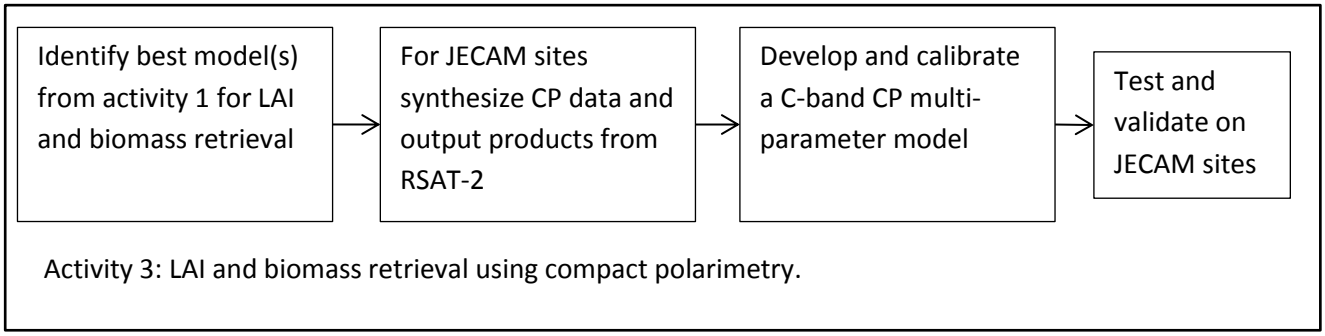
1- Adapt and test the available single- or multi-polarization LAI and biomass estimation models for different JECAM sites; this includes adaptation of the AAFC WCM approach to other JECAM sites, and testing other methodologies proposed by JECAM partners
2- Adapt and test these LAI and biomass estimation models to use multi-frequency data
3- Adapt and test these LAI and biomass estimation models to use compact-polarimetry data

The above activities are explained in the following diagrams. To complete these activities, we would collect remote sensing and ground data from the JECAM participants. These data would be shared among all the participants.




Activity 1: LAI and biomass retrieval using multi-polarized C-band SAR.




**Major milestones for Component #2**

| No. | Milestones | Starting date and ending date | Objectives | Deliverables |
|---|---|---|---|---|
| 1 | Determine participants and test sites | Q2 2017 | Contacting all the JECAM partners to see who is interested and what data are available in each site. Decide what crop types are to be modeled. | Spreadsheet |
| 2 | Data gathering | Q2-Q3 2017 | Gather, collate and document all the available satellite and ground data | Sets of preprocessed satellite imagery with ground measurements |
| 3 | Determine candidate LAI and biomass estimation models | Q2-Q3 2017 | Review the JECAM annual reports and literature to see what other LAI and biomass estimation models are available; consult with JECAM partners | Report |
| 5 | Data preprocessing and Q/C | Q3-Q4 2017 | Geometric and radiometric correction of radar data from JECAM sites. Q/C the processed data. | |
| 6 | Activity 1: Adapt | Q4 2017-Q3 | Adapt the AAFC WCM and other | Report-best |

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| | and test applicable LAI and biomass estimation models for use with the single- or multi-polarization data. | 2018 | JECAM participants' models for single- or multi-polarization approach. Compare the models over different JECAM sites. | practices |
| 7 | Annual report | Q1 2018 | Provide the end of first year report to CSA and JECAM partners | End of year report |
| 9 | Data preparation for the second activity | Q2-Q3 2018 | Gathering and pre-processing any new collected data | Sets of preprocessed satellite imagery with ground measurements |
| 10 | Activity 2: Adapt and test applicable LAI and biomass estimation models for use with the multi-frequency data | Q3 2018-Q1 2019 | Adapt the AAFC WCM and other JECAM participants' models for multi-frequency approach. Compare the models over different JECAM sites. | Report-best practices |
| 12 | Annual report | Q1 2019 | Providing the end of second year report to CSA and JECAM partners | End of year report |
| 13 | Data preparation for the third activity | Q1-Q2 2019 | Gathering and pre-processing compact polarimetry data | Sets of preprocessed satellite imagery with ground measurements |
| 14 | Activity 3: Adapt and test applicable LAI and biomass estimation models for use with compact-polarimetry data | Q2-Q4 2019 | Adapt and test LAI and biomass estimation models using the compact polarimetry data. Compare the models over different JECAM sites. | Report-best practices |
| 16 | Update the biophysical estimation tool | Q3-Q4 2019 | Add new crops into the available tool and update the coefficients for the available crops. | Updated tool |
| 17 | Documentation and training materials | Q4 2019-Q1 2020 | Provide guidelines for radar data preprocessing and the biophysical estimation tool. | Training documents |
| 18 | Publication | Q1 2018-Q1 2020 | Publish results in peer-reviewed Journals and present finding at international conferences. | Papers |
| 19 | Annual report | Q1 2020 | Provide the end of third year report to CSA and JECAM partners | End of year report |

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