### 4.2.3. Vegetation properties for cropland

**Objective:** To measure biomass and canopy water content to assess the effectiveness of vegetation parameterization associated with soil moisture retrieval models for both passive and active microwave sensors, at the SMAP scale.

**Measurement approach:**
A number of vegetation (VG) properties will be measured during SMAPVEX16-MB. Some of these properties are static (measured only once). Others are dynamic (require repeated measurements). Characterization of the vegetation is an important aspect of the SMAPVEX campaign and the level of effort to collect these measurements and samples will be significant.

The variety of crops grown in southern Manitoba is substantial. The number of different crops to be sampled will be largely determined by the prevalence of each crop in the region, modified by access granted by the land owners. The focus should be placed on major crops. Major annual crops to be targeted will include winter and spring wheat, canola, oats, corn and (soy)beans. Two fields of pasture/forage will likely also be selected.

The following static and dynamic vegetation properties will be measured.

Static Properties
VG1: Plant Count
VG2: Row Spacing
VG3: Row Direction

Dynamic Properties
VG4: Leaf Area Index (LAI)
VG5: Biomass and Canopy Water Content
VG6: Height
VG7: Phenology
VG8: Point Canopy Reflectance
VG9: Field Scale Canopy Reflectance

The sampling strategy will consist of collecting vegetation data at three sites per field, at least once per week. The change in vegetation structure, biomass and water content is significant during this period of peak growth and thus weekly measurements are warranted. Three of the 16 soil moisture sites will be selected for vegetation sampling. In 2012, sites 2 (on transect #1), 11 and 14 (both on transect #2) were selected. This worked well in 2012 as transit time through the field was optimized and yet the distance between sites ensured that a range of vegetation conditions were sampled. It is proposed that the same general approach will be followed in 2016. However, the effect of trampling of vegetation around the soil moisture sampling sites by the vegetation teams must be considered. Several options were considered to minimize this disturbance; however the team opted to move the sampling site by one during the second week of each campaign window. As such, sites 2, 11, and 14 will be sampled the first week of each campaign window whereas sites 3, 10, and 13 will be sampled the second week of each campaign window (Table 1).

**Table 1.** Location of the vegetation sampling sites for each week of the two field campaign windows.

| Campaign Window | | Week | Dates | Sampling Sites |
|---|---|---|---|---|
| 1 | June 8 – 20 | Week 1 | June 8 – 13 | 2, 11, 14 |
| | | Week 2 | June 14 – 20 | 3, 10, 13 |
| 2 | July 10 – 22 | Week 1 | July 10 – 16 | 2, 11, 14 |
| | | Week 2 | July 17 – 22 | 3, 10, 13 |

In addition, vegetation teams will be asked to take their samples 2-3 m away from the soil sample location to minimize disturbance at these sites. The number of replicates required for each vegetation parameter will also vary. These are detailed in the summary table (Table 5) at the end of this section.

**VG1: Plant Count**

The density of plants will be determined by counting the number of emergent plants in a row along a fixed distance of 1 meter. For each field, a small tennis ball will be lobbed towards a random location on the field. At the spot where the tennis ball lands, the center of the meter stick will be set down parallel to the closest row. The number of plants from one end of the meter stick to the other will be counted. This will be replicated for a total of 10 counts per field by moving perpendicular to the rows at each throw. Counts will be recorded on data sheets and used with row spacing to calculate plant density.

**VG2: Row Spacing**

Row spacing will be determined by measuring the distance between rows at each location where the plant counts are made. At each location, after the plant counts are made, the meter stick will be turned perpendicular to the row direction. At the soil level, the total distance will be measured between the centers of the two plant rows immediately adjacent on either side of the row on which the plants were counted. The distance will be divided by 2 to calculate average row spacing. Row spacing will be recorded on data sheets.

**VG3: Row Direction**

The direction of planting will be recorded (in degrees) using a compass, and using magnetic North as a reference. Thus, you will need to line up your N direction to the magnetic needle and record the direction of the row based on that reference. Correction of these readings to true North can be done afterwards.

**VG4: Leaf Area Index**

LAI will be captured using hemispherical digital photos. Seven photos will be taken along two transects (14 photos in total) at each of the three vegetation sites. These photos will be post-processed to estimates of LAI.

Some confusion in the collection of LAI led to errors in the 2012 campaign. As such, some modifications to the instrumentation and better training will be implemented in 2016. AAFC is fabricating telescopic light-weight aluminum poles upon which the camera is mounted. With these poles, cameras are suspended well above the crop canopy and thus only downward facing photos are necessary. The fixed pole also helps to maintain the camera lens level to the surface of the field. In this configuration, field crews no longer have to decide on upward or downward facing photos. For all crops (corn, soybeans, canola and wheat), all photos will be taken above the canopy during the first window in June. In July,

the same configuration is used for all crops except for corn, where photos will be taken upward instead. If resources permit, photos will be more closely reviewed following measurement dates to correct any problems during the data capture.

**VG5: Biomass and Canopy Water Content**

Vegetation biomass will be collected via destructive sampling. Canopy water content is derived from the biomass samples. One biomass sample will be collected per measurement site.

The approach to sample collection will be determined by the crop (Table 2). For canola, wheat, oats, barley, grassland and tame hay, a 0.5 m x 0.5 metre square will be placed over the canopy. All above ground biomass will be collected by cutting all vegetation at the soil level. This approach is also well suited for crops which are broadcast seeded, or which have very dense planting. For corn and soybeans fields, 5 plants along two rows (10 plants in total) will be collected. Knowledge of the density of the crop will permit scaling of these measurements to a unit area ($m^2$). Any weeds that are collected in the sampling plot are discarded in the field but should be noted on the data sheets if the amount is significant. Photos should also be taken for documentation purposes.

On vegetation sampling dates, three samples in total will be removed from each field (one biomass sample per sampling site). The specific samples sites will differ based on the sampling week for each of the field campaign windows. Please refer to Table 1 for specific dates and site locations. The goal will be to sample each field at least once per week.

**Table 2.** Biomass sampling strategies for each crop type.

| **Biomass Sampling Strategy** | **Crop Types** |
|---|---|
| 0.5 m x 0.5 m square | canola, wheat, oats, barley |
| 5 plants along two rows | corn and soybeans |

Samples will be first placed first in a mesh bag, and then a plastic bag to minimize water loss prior to weighing the wet sample. The mesh bag must be labeled with the date, field and site numbers on a label and then attached to the mesh bag with a zip tie. Vegetation will degrade rapidly (within a few hours) and thus weighing of the wet sample must be completed quickly. Thus during vegetation sampling days, the lab crew will have a temporary weighing station located on site. Crews are to bring their vegetation samples to the lab station when possible and convenient. To facilitate standardization and reduce errors, one team of two people will be assigned to weigh all samples. Wet weights are taken with the mesh and plastic bags (size of bags used and average bag weight must be pre-recorded). Following wet weighing, plastic bags are removed. If the samples are heavier than 1 kg, the vegetation plants must be subsetted to create a subsample of no more than 1 kg. The subsample will be left in the mesh bag and weighed immediately. Thus, it is important to try and keep the plants as intact as possible during the collection. Plants can be folded into the bag and broken as long as plant tissues are still connected. The mesh bag and subsetted sample will be placed in the air drying facilities at the U of M for a maximum of two weeks. The weight of the air-dry sample is then taken. For each field, one of the air-dry samples (from site 14 on week 1 and site 13 on week 2) will be placed in a plant drying oven at $60^o$ C for 48 hours to determine the oven-dry weight. The average ratio of oven-dry weight to air-dry weight for each crop will be multiplied by the

air-dry weight for each sample to correct the biomass to oven-dry basis. The oven-dry plant biomass will be used to determine plant canopy water content.

The lab crew will segment a specific sample by plant organs, i.e. from the sample at site 2 for week 1 and site 3 for week 2 of each field campaign window. There is an exception to this rule which is that all wheat biomass samples will be segmented into (a) stems+leaves and (b) heads. After segmentation, labels for mesh bags should include an additional descriptive: heads, leaves, stems, seeds/pods/cobs as appropriate. The level of segmentation will depend on the crop and is described in Table 3.

**Table 3.** Segmentation of the biomass sample required for each crop type.

| Segmentation / Crop Type | Sample A | Sample B | Sample C | Sample D |
|---|---|---|---|---|
| Wheat, oats, barley | Leaves / Stems | | | Heads |
| Corn | Leaves | Stems | Tassels | Cobs |
| Canola, soybeans | Leaves | Stems | | Seeds / Pods |

**VG6: Height**
Crop height can vary significantly and increasing the number of measurements will help to improve the accuracy of the average crop height. Plants that are collected from the biomass sample are used for this measurement. In total, 10 heights will be measured, 5 in each of two rows. For narrow-row crops such as wheat, oats, and barley, the height will be measured to the top of the upper most part of the canopy, whether leaf or fruit. Leaves are to be left in their natural orientation, and not extended, for this measurement. Heights can be measured before or after biomass sampling (whatever is easiest) and recorded on data sheets.

**VG7: Plant Phenology**
One lab crew (2 people) will be responsible for weighing the wet and dry biomass samples. The lab crew will also be tasked with recording the phenology of each biomass sample for a total of 3 phenology records per field. This determination will take place during the weighing process and recorded on data sheets. The BBCH scale will be used.

**VG8: Point multi-spectral crop scans**
Above canopy reflectance measurements will be collected in order to characterize the general crop condition and growth state in a number of optical and infrared wavelengths.

A Crop Scan multi-spectral instrument will be used to capture reflectance of the crop canopy. These reflectance data will only be collected on the first vegetation sample site (site 2 or 3 depending on the week) in each field. The crop scan measurements will be taken at approximately the same points at which the LAI photos are captured. This will yield 14 crop scan measurements (7 in each of two rows) for one vegetation site in each field.

**VG9: Field-scale multi-spectral crop scans**
A drone-mounted Micasense RedEdge 3 multispectral camera (Figure 1) will be used to acquire an image for the footprint of each field from which the soil moisture and vegetation samples are gathered. The camera acquires 5 spectral bands (Table 4). The drone schedule will be managed to facilitate the capture of a weekly image at each sample field

during the two-week June and July field campaign windows. In addition, a sample will be gathered once during the intervening 2 weeks, once prior to the June sampling period and once after the July sampling period (i.e. approximately 7 images per field over the growing season for a total of 350 images).

**Figure 1.** Micasense RedEdge 3 multispectral camera.

**Table 4.** Spectral Bands captured by the Micasense RedEdge 3 camera.

| Band Number | Band Name | Center Wavelength (nm) | Bandwidth FMHM (nm) |
|---|---|---|---|
| **1** | Blue | 475 | 20 |
| **2** | Green | 560 | 20 |
| **3** | Red | 668 | 10 |
| **4** | Red Edge | 717 | 10 |
| **5** | Near Infrared | 840 | 40 |

The spatial resolution of the camera images will be less than 10 cm. The drone carries a downwelling radiation sensor that senses the radiation in each of the 5 bands. These readings will be used to correct the measurement of the reflectance in each band. In addition, a Before-Flight Reflectance Panel will be used to capture a calibrated surface reading immediately before and after the flight on each field. The images will be captured in the 5-hour period bracketing solar noon (approximately 1:30 p.m. Central Daylight Time) which is from 11:00 a.m. to 4:00 p.m. When possible, the drone will be deployed just ahead of physical vegetation sampling on some fields on vegetation sampling days. On those dates, high resolution Normalized Difference Vegetation Index (NDVI) and enhanced vegetation index (EVI) values will be extracted from the vegetation sample locations to develop a calibration between the vegetation indices and the vegetation wet biomass and vegetation water content for each crop type.

For each date on which the drone is deployed at a given field, an area average NDVI and EVI will be calculated for the entire soil sampling footprint to provide a field-scale biomass and vegetation water content. However, this can be subsampled to any spatial resolution required.

A summary of the details for the vegetation sampling is included in Table 5

**Table 5.** Summary of vegetation sampling strategies.

| VegetationProperty | Number of sites per field | Replicates per site | Instrument | Temporal frequency | Description of approach | Assigned Team |
|---|---|---|---|---|---|---|
| **Static Vegetation Parameters** | | | | | | |
| **Plant Count** | 1 | 10 | Meter stick, tennis ball | once | Count number of plants along 1 metre | AAFC students prior to campaign |
| **Row Spacing** | 1 | 10 | Meter stick | once | Measure the distance of the two rows adjacent to the plant density count | AAFC students prior to campaign |
| **Row Direction** | 1 | 1 | Compass | once | Measure row direction using magnetic north as a reference | AAFC students prior to campaign |
| **Dynamic Vegetation Parameters** | | | | | | |
| **Leaf Area Index** | 3 | 14 | Camera and fish eye lense | once per week | 7 photos taken along 2 transects (14 in total) | Biomass Team |
| **Biomass and Canopy Water Content** | 3 | 10 plants for corn and soybean, 0.5 x 0.5m sample for every other crop | 0.5 x 0.5 m square | once per week | For canola, wheat, oats, barley, grassland, tame hay collect all biomass within square; For corn and soybeans collect five plants along each of 2 rows (10 in total) | Biomass Team |
| **Height** | 3 | 10 plants | Meter stick/tape measure | once per week | Measure height of plants that are collected from the biomass samples (10 plants, 5 in each row) | Biomass Team |
| **Phenology** | 3 | 1 | BBCH scale | once per week | Determine phenology for all three biomass samples | Lab Team |
| **Point canopy reflectance** | 1 | 14 | CropScan | once per week | One Crop Scan measurement for each LAI site (on site 2 or 3 of the field). | Biomass Team |
| **Field scale canopy reflectance** | Entire field | 1 | Drone-mounted Micasense RedEdge 3 camera | once per week, from May 30$^{th}$ to July 29$^{th}$ | | U of M. Team |