**LTAR**

**Sensor Recommendation Report**

**for the following types of Sensors**

1. **Meteorology, Soil Moisture, and Temperature**
2. **Water/Energy/Carbon Flux Tower**
3. **Wind Erosion**
4. **Imaging/Phenocam**

*(Draft – Feb. 7, 2015)*

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1. **Introduction**

The initial LTAR meeting in Nunn, CO initiated a discussion of types of observations to be made across the LTAR network and development of a list of recommended instruments to make these observations. The overriding purpose of these observations is to provide the data and measurements to meet the objectives of the LTAR Shared Research Strategy (reference). The Federal Government shutdown and sequestration resulted in an approximately six-month delay in LTAR budget allocations to the initial ten LTAR locations. Given the short time to initiate larger capital expenditures of LTAR equipment there was a considerable desire to identify relatively well-tested instruments that a number of locations had experience with, and confidence in. This resulted in development of a reduced set of recommended instruments. There where numerous concerns expressed that each LTAR locations did not have the necessary personnel with the right level of training to successfully deploy, operate, maintain, collect, QC, and analyze several classes of measurements. Therefore, in addition to consulting in-house experts to recommend instruments, they were also asked to identify labor and expertise requirements to carry out the tasks listed noted above for a several measurement classes.

**II. Measurement Classes**

An instruments breakout group was conducted at the Nunn, CO meeting and recommended developing instrument recommendations for the following classes of measurements:

1. Meteorology and Soil Climate
2. Water/Energy/Carbon Flux Towers
3. Wet/Dry Atmospheric Deposition
4. GRACEnet
5. Wind Erosion
6. Imaging

Post breakout discussions with the entire group further reiterated the need for skilled personnel for various instruments and measurements. The GRACEnet group noted the rapid evolution in measurement technology and the possible tradeoffs between newly emerging, and capital intensive, automated technology, versus the need for more highly skilled personnel. It was further noted that for each of these measurement classes, supporting hardware (mounting brackets, exclosures, etc.), power needs (solar panels, batteries); datalogging, and data telemetry (radio, cell phones), would be required. The focus of this document is not to specify in detail all of this auxiliary hardware. However, based on existing experience, a number of these items that have been reliably used at various locations have been included in the attached spreadsheets to provide suggestions to those locations without experience.

The following **areal and off-site** measurements were identified but tabled for instrumentation purchase discussions as the scale, number, and placement of these classes of measurements would be dependent on the design of the business as usual and enhanced production experiments.

1. Runoff
2. Erosion and sediment transport
3. Groundwater monitoring
4. Water Quality

Appendix A contains the post-meeting correspondence to obtain estimates for labor, skill level of labor, recommended instruments in a subset of the measurement classes, and an inventory of instruments in these classes at LTAR locations. Estimated labor and skill level requirements are listed below.

*IIa. Labor and Expertise Requirements Reponses*

* 1. Met/Soil Climate
     1. Gulf Coast – 2 Techs
     2. WG, Great Basin, Gulf Atlantic Coastal Plain (ARS-Tifton) – 1 Tech, 1 Support Scientist (SS) under supervision of 1 SY
     3. Lower Chesapeake Bay (ARS-HRSL) – 0.25 SS
  2. Water/Energy/Carbon Flux Tower
     1. Flux Group – for two systems (1 SY, 1 Tech devoting part time at each site)
     2. Lower Chesapeake Bay (ARS-HRSL) – 0.25 SS, 1 tech
     3. Or if there was one office to run most of them out of (for those sites without an SY to support them), then 1 SY, 1 PD, 1 or 2 techs devoted specifically to this effort.
  3. Wet/Dry Deposition
     1. Work with NADP (from Nunn meeting), no specific recommendation
     2. Would need analytic support lab
  4. GRACEnet
     1. Labor intensive and complex – no specific recommendation – but based on meeting discussions a Cat. 1 Scientist or Post-Doc, and a Technician and analytic lab plus expertise to process large numbers of samples. The
  5. Wind Erosion
     1. Post – installation 1 tech, 10% of time (See Appendix B for more detailed times, tasks and responsibilities between the LTAR site and the Jornada Experimental Range)
  6. Imaging
     1. Technician – 1.5 days every two months (9 days/year = 0.04 person/year)
  7. Radio/Telemetry
     1. 0.2 Tech, 0.1 SS

Subsequent e-mail correspondence indicated that GRACEnet instrumentation purchases needed more discussion and purchases for FY14 were tabled. Wet/Dry deposition discussion indicated that the existing NADP network may be sufficient for LTAR needs. Imaging needs at this time were restricted to acquisition of phenocams for flux stations. The National Phenocam Network has well developed instrumentation and installation protocols (<http://phenocam.sr.unh.edu/webcam/> and see Appendix C). Therefore instrument and purchase recommendations were only developed for:

1. Meteorology and Soil Climate
2. Water/Energy/Carbon Flux Towers
3. Wind Erosion

*IIb. Instrument Recommendations*

Table 1 presents the core set of meteorological, soil, and eddy covariance measurements needed at the major land cover and management alternatives across the LTAR network. For the measurements outlined, as well as auxiliary equipment, there are often several options for manufacturers and suppliers for much of the equipment needed. It matters not which manufacturer and model are used so long as they are from a reputable company with documented calibrations and specifications. For most of these sensors, calibrations are tied to specific standards, but the calibration of the soil moisture sensors to the specific site soils is needed. Likewise, field and laboratory instrument re-calibrations (or calibration checks) must follow manufacturer recommendations. Specific to the eddy covariance instrumentation, it is important to establish a “roving” LTAR standard (or if feasible, use Ameriflux’s; <http://ameriflux.lbl.gov/tech/site-visits/>) that can be roamed to the different sites in order to benchmark and insure eddy covariance fidelity.

A spreadsheet of instrument recommendations, suppliers, costs, maintenance, calibration needs, and general notes were developed for the three measurement classes above and for radio and telemetry options. The spreadsheet contains five tabs whose contents are described below. An e-copy of the spreadsheet is attached as they are not easily printed on paper. The files can also be downloaded from ??

Instrumentation Recommendation Spreadsheet (File: LTAR-Instr-Recom-Feb-7-2015-v1.docx)

* 1. Tab 1 – LTAR-Met-Flux-Table 1
     + A copy of Table 1 shown below that also includes additional columns the instrument recommendations with supplementary information

2. Tab 2 – LTAR-Flux-Recom

* + - Flux tower instrumentation recommendations (some repeated from Tab 1) with recommendations for auxiliary hardware, power, etc information.
  1. Tab 3 - LTAR–Met Recom
     + Stand alone Met Site instrumentation recommendations
  2. Tab 4 – LTAR-Telem-Radio
     + Telemetry and radio equipment options largely drawn from the ARS Southwest Watershed Research Center, Tucson, AZ (Walnut Gulch LTAR) that have be reliably used for over a decade
  3. Tab 5 – LTAR-Wind Erosion
     + Wind Erosion instruments and hardware – NOTE: not fully finalized

Note that there are common instruments between different measurement classes, especially Flux Tower and Met Station. Depending on the location and experimental design the need to purchase some instruments could be reduced.



*IIc. Availability of Expertise to Install, Maintain, Analyze Water/Energy/Flux Tower within LTAR Labs*

Various LTAR locations indicated they did not have sufficient in-house expertise to install, maintain, QA/QC and analyze flux tower data. Several indicated they may not have sufficient funds to hire the necessary expertise in this area. LTAR conference call discussions bought up how we might address the flux tower needs of locations without expertise in the near term or if a central pool of persons (existing staff and/or new hires) might provide network support for flux tower measurements and analysis. With this in mind another poll was conducted requesting the following information:

1.     List your LTAR Location and primary Lab responsible for that location

2.     Does your location have a person on staff who has the expertise to set up, operate, maintain, QA/QC data for a energy/CO2/Met flux tower?

3.     Do you have a trusted collaborator who will perform the items in question 2?

4.     Do you intend to hire a person to perform the items in Q2?  If so, what level of experience/education?

Complete poll results are included in the attached spreadsheet (filename: LTAR-Flux-Poll.xlsx) and are summarized in the following table.



Responses in the attached file include not only simple answers but also include responses with a number of caveats.

**III. Moving Forward**

In developing instrument recommendations, the expert groups noted that some measurements (e.g. soil moisture among others) could be made by instruments from numerous companies. They noted that some sensors might have proven to work better under some environmental conditions and not others (see discussion by J. Sadler in file: Comments from Jan-24-2015-Request.docx and Appendix D). A number of LTAR locations already have instruments, observations, and data QA/QC protocols in place for a number of the measurement classes discussed above. A decision must be made if uniformity of instruments across all LTAR locations is essential. Or is it adequate to have a variable measured by different sensors to community accepted standards. If uniformity is required, it is recommended that the expert groups for each measurement class be consulted to come up with a consensus sensor recommendation.

In addition to the measurement classes discussed above the complete list of classes to be implemented at all LTAR sites has not been finalized. Some that have come up in discussions include:

1. Plot/field scale runoff & erosion and off-site water quality measurements (discussed at Nunn but were put off for future consideration as they require more thought for design – Mark Nearing and Greg McCarty were ID’ed as subject experts)
2. Agronomy/plant physiology (how do we consistently measure business as usual vs enhance productivity across sites)
3. Entomology

It is recommended that these classes, and others, be discussed amongst the LTAR participants to develop a draft final list of measurements for LTAR. Experts in these measurement classes should be consulted to recommend instruments, experimental design, and measurements procedures. If specially trained expertise is needed for these measurements it should be identified and a similar poll conducted across LTAR locations to assess where this expertise exists and how locations without in-house staff in these areas can be assisted in either training existing staff or hiring new staff.

In addition to instrument purchase recommendations a number of other issues related to overall LTAR observations for all measurement classes must be addressed along with associated labor and skill requirements. They include:

1. Systematic Maintenance and Calibration of Instruments
2. Routine Data Review
3. QA/QC, Data Management & Delivery, and Archiving

**Appendix A. LTAR Expertise Survey and Sensor Request Letter**

DATE: June 1, 2014

TO: All LTAR locations

TOPIC: \*\* URGENT \*\* Sensor Needs and Inventory – June 9 Deadline

FROM: David Goodrich

At the LTAR meeting I was tasked to develop a list of LTAR sensors and equipment that could be purchased this fiscal year for all 18 LTAR locations. Note that unfunded LTAR locations have been paired with funded locations to facilitate purchases. Given the time required for procurement of expensive items, a deadline to have the requested information has been set for June 16, 2014. Please carefully read the attached file “LTAR Instrumentation and Sensor Recommendations.docx” (copied below). To ensure effective and non-duplicative purchases the following two classes of information are requested by June 9, 2014.

***Information from Expert Sub-Groups for each class of LTAR observations***

NOTE: I am arbitrarily selecting (imposing) on persons I know who have expertise (or I think they do). If there are others at your location who can better do this, please request they do so ASAP.

NOTE: If you sub-group cannot fully coordinate responses please proceed as individuals or get those that you can together. We do not have time to wait for someone to come back from vacation.

1. Meteorological/Soil Climate Station -Tim Keefer, Mark Seyfried, Dave Bosch, Mike Cosh
2. Water/Energy/Carbon flux tower - Russ Scott, John Prueger, Gerald Flerchinger, Bill Kustas
3. Wet/Dry Atmospheric Deposition – (Tom Potter and Cathleen Hapeman (Tifton) mentioned by D. Bosch on 2/3/15; see comment by T. Potter in “Auxiliary Comments-2-6-15.docx” file) Also see http://nadp.sws.uiuc.edu/lib/
4. GRACENET - Dave Higgins, Erik Hamerlynck, Phil Robertson, Michel Cavigelli, Mark Liebig
5. Wind Erosion - Kris Havstad
6. Imaging System (Phenocam+)- Mary Nichols, Tala Awada, Guillermo Ponce, Mark Seyfried
7. Radio/Telemetry Base and Relay Station - Tim Keefer, Fred Pierson (Boise Instru. Specialist)

***Inventory of Instruments – Observation Types already in place at LTAR sites***

EACH location provide an inventory of the type and number of instruments / observations systems they have at their location.

Please accept my apologies in advance for the short notice and very direct nature of this request.

Print out of “LTAR Instrumentation and Sensor Recommendations.docx”

**LTAR Instrumentation and Sensor Recommendations and Location Inventories**

**(DRAFT – May 31, 2014)**

***Intent***

* The intent is to ensure that data collected are intercomparable and “NEON like”. It does not imply that all locations will have the same instruments, installed exactly the same way. If your location has comparable observation infrastructure and can produce high level, QC’ed data products, that is alright. *Ask yourself this question:* What level of uniformity in instrumentation, installation, and observation frequency would you want if you had to conduct a network level analysis for a journal paper?
* While not insisting on uniformity of instrument there are some advantages to moving toward uniformity as the LTAR network develops or as your location replaces existing equipment. Example: If we all use the same data logger it will be much easier to share programs and for folks at one locations to assist another.
* At this time we don’t need to spec out every nut and bolt of instruments needed (although this may be needed in the future) we need a good idea of the primary instruments and equipment needed for each observation class, whether your location has them already, and the level of expertise required.

***Assumptions***

* For each LTAR at least 2 sets of instrumentation be acquired to collect observations on a “business as usual” situation and a “intensified agricultural production” situation
* The systems can be re-locatable
* The systems can operate without AC power
* To the extent possible the system and instruments should be automated
* To the extent possible, automated systems will have data logging and telemetry capabilities
* Once the equipment is purchased, installation specifications and protocols will have to be developed to strive for uniformity

***Information Needed from Expert Sub-Groups for each class of observations***

NOTE: I am arbitrarily selecting (imposing) on persons I know who have expertise (or I think they do) in the following areas to fill out the requested information in the attached spreadsheet “LTAR sensors.xlsx”– see the first tab – “LTAR” – printed below). If there are others at your location who can better do this, please request they do so ASAP. I have attempted to select persons from multiple locations covering a range of conditions.

NOTE: If you sub-group cannot fully coordinate responses please proceed as individuals or get those that you can together. We do not have time to wait for someone to come back from vacation.

*Class of observation:*

1. Meteorological/Soil Climate Station
   1. Sub-Group Experts - Tim Keefer, Mark Seyfried, Dave Bosch, Mike Cosh
   2. Also see GraceNet Met station protocols for guidance
   3. Also see tab 3 – “Smart-Forest”
2. Water/Energy/Carbon flux tower
   1. Sub-Group Experts - Russ Scott, John Prueger, Gerald Flerchinger, Bill Kustas, John Baker, Joe Alfieri, (Note: Daren Harmel (ARS, Temple) requested Hal Collins be added to this group on 12/18/14)
3. Wet/Dry Atmospheric Deposition
   1. - ?? Who can help ??
   2. Also see http://nadp.sws.uiuc.edu/lib/
4. GRACENET
   1. Sub-Group Experts – Dave Higgins, Erik Hamerlynck, Phil Robertson, Michel Cavigelli, Mark Liebig
5. Wind Erosion
   1. Sub-Group Expert - Kris Havstad
6. Imaging System (Phenocam +)
   1. Sub-Group Experts – Mary Nichols, Tala Awada, Guillermo Ponce, Mark Seyfried, (Note: Dawn Browning, ARS-Jornada, requested to be added to this group on 12/18/14 and supplied a summary write-up on 12/29/14)
7. Radio/Telemetry Base and Relay Station
   1. Sub-Group Expert – Tim Keefer, Fred Pierson (Boise Instru. Specialist)
   2. Also see tab 3 – “Smart Forest” lower portion

* For each class of instrumentation / observations listed below the following information is also needed and there is a placeholder for each in the spreadsheet:
  + Level of expertise required (e.g. Tech., support scientist, post-doc, scientist) to operate, maintain, collect data, QC data, and analyze the data to useful products (e.g. Ameriflux Level 4 data levels – see attached file)
  + Estimate of the amount of time (person-years) of persons with the appropriate expertise to operate, maintain, collect data, QC data, document the data, and archive the data (assume that some database structure and data entry procedures will be developed)
  + What auxiliary equipment (not-field deployed) is required to provide high-quality data products (e.g. calibration equipment, a gas chromato-graph to analyze non-automated chamber based measurements, etc.)
  + For each large ticket item (>$2,500) can you provide your opinion as to whether we can: 1) “buy - purchase now” (i.e. it is tested, reliable, and is capable of making research quality measurements) or 2) “wait - requires more investigation” realizing we can’t wait for the next level of technology to come on-line
  + An estimate of the maintenance and calibration frequency
  + An estimate of the useful life of the instruments – replacement schedule
  + A reasonable estimate of the number of spare instruments that should be purchased and available to minimize gaps in observation continuity
  + Where the instrument is available (Web link)
  + In the “NOTES” – column in the “LTAR” tab - For large ticket items (>$2,500) please comment, using your experience, on the trade-offs between more expensive automated equipment and alternate equipment in terms of: 1) reliability, 2) life-span, and 3) labor savings – NOTE: This may require a separate WORD file. If you develop a separate file please list the name of the file in the “notes” column in the attached spreadsheet

***Inventory of Instruments – Observation Types already in place at LTAR sites***

To effectively spend funds this fiscal year we do not want to duplicate satisfactory instruments already in place. I’d ask that EACH location provide an inventory of the type and number of instruments / observations systems they have at their location -

see second tab in attached spreadsheet –“Inventory”

***Areal and off-site measurements*** (not discussed in detail at the May 2014 LTAR meeting). We will not focus on making purchases for these observations this fiscal year but must do so early in the next fiscal year.

1. Runoff
2. Erosion and sediment transport
3. Groundwater monitoring
4. Water Quality

**Appendix B:** **Wind Erosion - Outline of Tasks and Responsibilities**

Developed by: Nick Webb (USDA-ARS, Las Cruces, NM)

Note: Time estimates are for one site.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Task** | **Time Required**  **(Duration)** | **Time Required**  **(Frequency)** | **Personnel Required** | **Who is Responsible** |
| Site selection | 1 day | 1 |  | LTAR in collab-oration with JER. |
| Equipment purchasing/acquisition | 5 days | 1 | 1 | - LTAR Sites.  - JER provides detailed list |
| Equipment construction  (MWAC samplers, MWAC masts/fins, meteorological tower hardware) | 10 days (samplers) – student tech.  5 days (masts/fins) – simple welding.  1 day (hard-ware) simple fabrication. | 1 | 1 | - LTAR Sites.  JER provides guidance and instruction for other sites. |
| Met. Equip. Prep and testing | 2 days | 1 | 1 | LTAR Sites |
| Site equipment installation | 14 days | 1 | 2 | LTAR Sites support by JER as needed. |
| Site description | 0.2 days | 1 | 1 | LTAR / JER support |
| Soil sampling | 0.2 days | 1 | 1 | LTAR / JER support |
| Soil sample analysis | 2 days | 1 | 1 | JER |
| Veg. survey (LPI, canopy height & gap) | 2 days | 4 x per year (minimum) | 2 | LTAR Sites with training from JER |
| MWAC sample collection | 0.5 days | 12 x per year (monthly) | 1 | LTAR Sites with training from JER |
| MWAC sample weighing (Off or Lab) | 0.5 days | 12 x per year (monthly) |  | LTAR Sites. |
| Data transfer to JER (Veg. and MWAC) | 0.2 days | 12 x per year (monthly) | 1 | LTAR Sites. |
| Equipment servicing/repairs | 1 days | 2 x per year | 1 | LTAR Sites with support of JER. |

* Site location and establishment will be coordinated with JER support.
* Soil sample analyses will be conducted by Jornada Experimental Range (JER) and provided to all sites.
* Data processing will be conducted by JER and provided to all sites.

**Appendix C. Phenocam Sensors for LTAR Tower Instrumentation**

Developed by: Dawn Browning (USDA-ARS, Las Cruces, NM), and Guillermo Ponce (USDA-ARS, Tucson, AZ)

The cost per unit which includes the five Megapixel color-infrared camera, 6.2mm lens, and outdoor exclosure is $950.00 (quote in file: Phenocam-Quote\_USDA-ARS\_Tucson\_7380.pdf). One camera for each treatment (aspirational, “business as usual” agriculture) is recommended. This is based on the assumption that there would be a flux tower in each treatment area. Telemetry or cell connectivity via the flux tower and costs associated with data transmission are not included in the $950.00/camera quote).

The cameras are web-enabled, providing remote access to visualize the greenness patterns in real time as well as to transmit images to an FTP server at the University of New Hampshire as part of the National Phenocam Network (http://phenocam.sr.unh.edu/webcam/). The data are archived there and available for download. The frequently asked questions (FAQ) page of the National Phenocam Network (<http://phenocam.sr.unh.edu/webcam/faq/>) provides a wealth of additional information for installation and operation of phenocams. Installation instructions are contained in the file: Phenocam\_Install\_Instructions.pdf.

Once the cameras are installed, data maintenance needs for the phenocam images are minimal. They are archived as part of the Phenocam Network; both raw images and greenness values are available for download. Based on experience at the Jornada Experimental Range, it has been one of the easiest data streams to use and manage. We have occasionally received notices from someone at the Phenocam Network that no images had been received for a few days; each time, a Biological Science Technician solved the problem with our solar panel array.

1) Level of expertise required (e.g. Tech., support scientist, post-doc, scientist) to operate, maintain, collect data, QC data, and analyze the data to useful products. A t*echnician can trouble-shoot occasional problems with power or camera configuration.*

2) Estimate of the amount of time (person-years) of persons with the appropriate expertise to operate, maintain, collect data, QC data, document the data, and archive the data (assume that some database structure and data entry procedures will be developed).

*This time is minimal because of support provided by the National Phenocam Network. I would estimate 1.5 days every two months (9 days/year = 0.04 person/year).*

3) What auxiliary equipment (not-field deployed) is required to provide high-quality data products (e.g. calibration equipment, a gas chromato-graph to analyze non-automated chamber based measurements, etc.).

*Not applicable. There is no good calibration protocol for the phenocams. Even if one were to mount a white panel in the field of view, there are no established protocols for adjusting the digital numbers in the image. The primary data product from the phenocam images are estimates of greenness that are processed (using tools provided by the National Phenocam Network) robustly to characterize patterns of primary productivity.*

4) An estimate of the maintenance and calibration frequency.

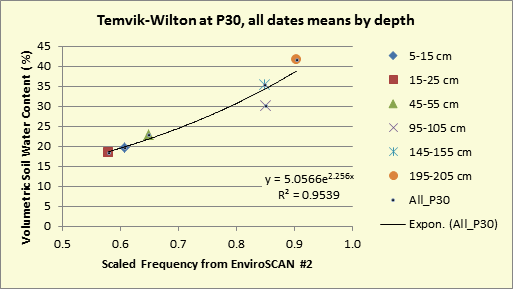
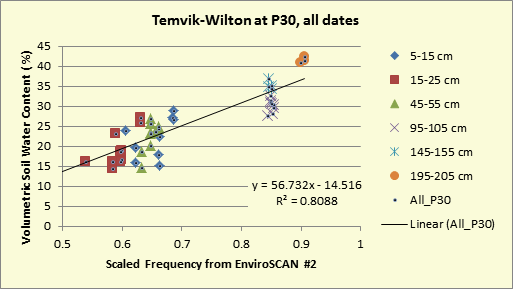
*Not applicable. See above.*

5) An estimate of the useful life of the instruments – replacement schedule. A reasonable estimate of the number of spare instruments that should be purchased and available to minimize gaps in observation continuity.

*We have had our cameras up for two years and others as part of the National Phenocam Network have been operational since 4/4/2008. A reasonable and conservative expectation is that the cameras would operate for at least six years.*

**Appendix D. Soil Moisture Probe Justification from NP-LTAR (ARS Mandan, ND)**

EnviroSCAN soil moisture probes have provided accurate soil water content data under variable moisture conditions at NP-LTAR. Evaluations throughout the 2014 growing season found calibrated probes provided excellent data when compared to a standard soil core water content method for a Temvik-Wilton silt loam (R2 = 0.81, nine measurement dates; R2 = 0.95, dates aggregated). The small installation footprint, flexibility to customize multiple depth increments (up to six over a 2-m depth), and interface with available dataloggers have been notable benefits. Given outcomes from 2014, EnviroSCAN soil moisture probes will be deployed at NP-LTAR sites.



Real-time data from NGPRL EnviroSCAN probes may be accessed at <http://np45-webdata/sandyloam_w3b/index.html>.

Additional information about EnviroSCAN probes may be accessed at <https://www.campbellsci.com/enviroscan-overview>.