REPORT TO THE NORTH AMERICAN 4R RESEARCH FUND (FERTILIZER CANADA AND IPNI). Y1 2015-2016

DEVELOPMENT OF DECISION SUPPORT MECHANISMS FOR 4R OPTIMIZATION OF NITROGEN FERTILIZATION PLACEMENT, RATE AND TIMING BASED ON THE INTEGRATED USE OF SOIL, WEATHER AND MARKET DATA

Activity 10 (CA) and Activity 10 V-1 (CRDA)

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BY: NICOLAS, TREMBLAY, AGR., PH.D., AGRICULTURE AND AGRI-FOOD CANADA

NICOLAS.TREMBLAY@AGR.GC.CA

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INTRODUCTION

This report is an update for the first year of Activity #10 in the Canadian Fertilizer Institute's project entitled "A Canadian Research Network to Improve 4R Nutrient Stewardship for Environmental Health and Crop Production." Activity #10 is entitled "Development of decision support mechanisms for 4R optmization of nitrogen fertilization placement, rate and timing based on the integrated use of soil, weather and market data."

ACTIVITY 10 OBJECTIVES

GENERAL OBJECTIVE

To increase nitrogen use efficiency by managing the uncertainties affecting the 4R fertilization process.

GENERAL WORKPLAN

- Assemble databases from suitable past experiments and merge with metadata
- Merge data from currently developing experiments
- Modelling: development, test and validation of models according to different approaches
    - Multifactorial, state equation, fuzzy logic models will be tested. The best suitable to perform probabilistic and sensitivity analyses will be retained
    - Historical data of crop response to N fertilizer according to critical parameters (soil-growth-weather) gathered from previous projects will be used
    - New data will be used to validate and/or calibrate and adjust the model
- Achieve a risk assessment on optimal N recommendations in a context of uncertainty in the estimation of critical seasonal weather parameters (actual and forecast) and other inputs (soil data and growth state according to multiple sources of assessment; N and harvest prices)
- Extract rules and key indicators from the above results in order to design decision-support systems suitable for each production context
- Dissemination activities through participation in conferences, workshops, and interactions with crop producers and agribusiness representatives.

Y1 OBJECTIVES AND STATUS

DATASETS ASSEMBLAGE

Datasets assemblage: from AAC GAPS and SAGES projects as well as from past N losses studies from colleagues in the project. Define the structure of the geospatial database and decide on the software framework. Inventory data and meta-data available by crops. Identify needs for complementary soil and weather meta-data / obtain. Organize and structure the DB.

- Databases of the past AAFC's GAPS #333 (Tremblay et al.) and SAGES (Grant et al.) projects are available.
- Data gathered in a precision farming context (ground-truthing, yield monitoring, imagery) is concealed in a geospatial database. ArcGIS has been selected to extract information from the geodatabase which is classified by theme, projects, sites, years. The database contains feature datasets, raster datasets (images) and the related meta-data. Currently, this database contains strip N trials results from commercial sites in the Montérégie region (plain of Montreal) of Quebec. The sites in the database are: Gasser 2011, Deringer 2011, Landry 2012, Alix 2013, Letellier 2013, Lanciault 2013, Beaudin 2014, Landry 2014, Alix 2015, Lanciault 2015 and Letellier 2015.
- Data from the N experiments databases produced by the contributing scientists within and outside of the CFI group will be analyzed using the meta-analysis approach, which is suitable for the extraction of knowledge from such grouping of at-first motley trials. Indeed, these trials are formatted differently and characterized by different data and metadata structures.
- Part of the work started since 2012 (and continuing with this project) is to collect and restructure these databases and prepare them for meta-analysis. The constitution of a Quebec – Ontario corn DB has been prioritized which contains 322 site-years of trials on sidedressed N. A first meta-analysis has been conducted and a first resulting report is available here (Tremblay, N. M.Y. Bouroubi, C. Bélec, E. Fallon. 2015. Meta-analyses on an Eastern Canada database of in-season corn nitrogen response trials. Symposium Meta-Analysis Applications in Agricultural Research. ASA-SSSA-CSSA-ESA 2015 Meeting. Minneapolis. November. Oral.)
- The inventory of data and meta-data available by crops is going on. As we move from corn to the other crops covered by the project, the needs for complementary soil and weather meta-data specific to those crops are identified and the data seeked.
- For each original database, a first output (called Output1) was (or will be) produced in the form of a restructured DB. The format of Output1 is common to all DBs and contains complete raw information on data (yield for several N rates) and meta-data (dates, location, soil, weather, management practices, cultivar, etc.). Generally, weather metadata (daily T_{min}, T_{max}, rainfall) are stored in a separate sheet of the same Excel file.
    - The format of **Output1** DB was defined as follows:
        - LAT : latitude of the field

- LONG : longitude of the field
- TOWN : name of location (municipality, town, village)
- SITE : site name
- FIELD : field name or number
- YEAR : year of the collected data
- CROP : crop type
- PREV : previous crop
- CULTIVAR : name of cultivar
- CHU_CV: corn heat units of the cultivar
- SEED_RATE : seeding rate per hectare
- TILLAGE : tillage (conventional or conservation)
- SOW_DATE : sowing date
- SPLIT_DATE : split application date
- No_DAY: number of days between sowing and split application
- HARVEST_DATE : harvest date
- ATXR : soil surface textural class (horizon A)
- ASAND : percentage of sand in the soil surface (horizon A) (%)
- ASILT : percentage of silt in the soil surface (horizon A) (%)
- ACLAY : percentage of clay in the soil surface (horizon A) (%)
- SOM : soil surface organic matter (%)
- PH : soil surface pH (pH H_2O or pH KCL)
- XX_NXXX_depth : soil nitrate (NXXX=NO3N) or ammonium (NXXX=NH4N) at sowing (XX=SOW), split (XX=SPLIT) or harvest (XX=HARVEST) for depth of 0-15 cm, 0-20 cm, 0-30 cm, etc (depth=015, 020, 030) (kg N/ha)
- SOIL_X_depth : phosphorus (X=P) or potassium (X=K), etc in soil for depth
  of 0-15 cm, 0-30 cm (kgX/ha)
- NSOW : Nitrogen fertilizer rate applied at sowing (kg N/ha)
- NSOW_SOURCE : Nitrogen fertilizer source at sowing
- NSOW_APP: Nitrogen fertilizer application method at sowing
- NSPLIT : Nitrogen fertilizer rates applied at split application (kg N/ha)
- NSPLIT_SOURCE : Nitrogen fertilizer source at split application
- NSPLIT_APP: Nitrogen fertilizer application method at split application
- NTOT : total Nitrogen fertilizer rate (NSOW+NSPLIT) (kg N/ha)
- MANURE : manure history
- P : Phosphorus fertilizer rate applied (kg P_2O_5/ha)
- K : Potassium fertilizer rate applied (kg K_2O/ha)
- NOPT : optimal Nitrogen (kg N/ha)
- NoREP : number of replications
- GRAIN_MOIST : grain moisture (%)
- YIELD : grain yield (t/ha)

- The weather sheet contains the following columns:
  - The Julian day of the year
  - The maximum daily temperature in °C
  - The minimum daily temperature in °C
  - Daily precipitations in mm

    - Daily irrigation in mm, if applicable
- Another restructured DB (called Output2) is produced from Output1 by keeping only the processed data that are used for meta-analysis. The **Output2** DB is designed to be simple to use for meta-analysis processing. It contains the following fields:
    - IDENTIFICATION : concatenation of the fields 'TOWN'_'SITE'_'FIELD'_'YEAR'
    - CROP : crop type
    - PREV : previous crop
    - TILLAGE : tillage (conventional or conservation)
    - ATXR : soil surface textural class (horizon A)
    - ASAND : percentage of sand in the soil surface (horizon A) (%)
    - ASILT : percentage of silt in the soil surface (horizon A) (%)
    - ACLAY : percentage of clay in the soil surface (horizon A) (%)
    - SOM : soil surface organic matter (%)
    - CHU_m30p15 : Corn Heat Units calculated from 30 days before split application to 15 days after (46 days)
    - PPT_m15p15 : cumulative precipitation (daily rain mm) calculated from 15 days before split application to 15 days after (31 days)
    - SDI_m15p15 : Shannon diversity Index calculated from 15 days before split application to 15 days after (31 days)
    - AWDR_m15p15 : abundant and well-distributed rainfall (PPT * SDI)
    - NSOW_CONTROL : Nitrogen fertilizer rate applied as control at sowing (kg N/ha)
    - NSPLIT_CONTROL : Nitrogen fertilizer rate applied as control at split (kg N/ha)
    - NSOW : Nitrogen fertilizer rate applied at sowing (kg N/ha)
    - NSPLIT : Nitrogen fertilizer rate applied at split (kg N/ha)
    - Y : a variable called « effect size » used for meta-analysis. Y is the average over replications of log(RR), where RR is the response ratio defined by: RR=Yield/Yieldcontrol
    - VY : is the pooled variance of Y over the replications
    - DF : degrees of freedom of Y (DF = NoREP – 1)
- The new DB obtained during the Y1 period covered by this report is summarized in **Table 1**.
- Weather data are available from experimental farms or from Environment Canada weather stations. The structuring of the DB was performed using Matlab programming.

NEW DATA COLLECTION

Collect new data from current parallel AAC project (Tremblay et al. - Nopt)

- Fields added during Y1 in the geodatabase were Alix 2015, Lanciault 2015 and Letellier 2015.

MODELING

Modeling from historical data and initiate the tests of multifactorial, state equation and fuzzy logic approaches

- A 5 k CAD contract was granted to Valacta, the dairy production centre of expertise for Quebec and the Atlantic dedicated to improving the profitability and the sustainability of dairy farms by sensitizing producers to the multiple aspects of techno-economic performance of their herd and its' management. Valacta has been selected for its capacity in:
    - The development of knowledge and transfer of technology to farms;
    - Data collection, sample collection;
    - Treatment of production data using information technology and data transfer.
- The methodology used was to get familiar with the Quebec-Ontario DB (322 site-years), to understand the fuzzy inference system already deployed by Dr. Tremblay's team for corn N fertilization, to link the DB to the FIS using Matlab, and to develop algorithm to find "optimal" membership functions. The membership functions were optimized using the following steps:
    - Use simple numerical optimization
    - Generate random points for membership functions (MF)
    - Calculate RMS errors (observed vs predicted N rate)
    - Loop 200-1000 times and keep MF parameters that lead to lowest RMS
- The work is going on and the report will be delivered before March 31st, 2016.

PROBABILISTIC EVALUATIONS

Establish a statistical framework for managing uncertainties on soil, crop status and weather assessment (spatial and temporal)

- The statistical framework for managing uncertainties is being developed using, among other references, the methods proposed in the book *Computational Intelligence for Knowledge-Based Systems Design* (reference below).
- In cooperation with our partner at McGill University, Dr. Viacheslav Adamchuk, a post-doc candidate with outstanding qualifications has been identified and will be hired for Y2 and Y3. This PDF will be supported by Dr. Adamchuk and his staff of graduate students.
- Another 5 k CAD contract will be issued to a specialist on numerical optimization to handle the database constituted around forecast and effective daily 2015 summer precipitations in selected sites of the Montérégie area in Quebec. The optimization will focus on the data provided by the North American Ensemble Forecast System (NAEFS) provided by Environment Canada.

DECISION-SUPPORT SYSTEM

Identify decision-support system components and implementation options, implement two-level control option: 1) overall field rate and 2) spatial differentiation when appropriate

- Decision-support system components for overall field rate and other 4R parameters will be derived from meta-analyses.
- Decision-support system components for spatial differenciation will harness available "precision farming" databases.

OTHER VALUABLE INFORMATION

- Dr. Tremblay participated in an international workshop of the *Interest Group on Agriculture Data* (IGAD) of the *Research Data Alliance* (RDA). The IGAD pre-meeting was held at INRA building, 147 Rue de l'Université from 21 to 22 of September 2015. The RDA 6th Plenary Meeting was hosted in the *Conservatoire national des arts et métiers* (Cnam), Paris from 23-25 September 2015. The travel report is available here. The report is a summary of lessons learned and information gathered while attending the event and we believe it constitutes a "crash course" on the status of research data sharing today and of the way forward.
- A new book has been purchased within the frame of this project: Computational Intelligence for Knowledge-Based Systems Design – 2010. Editors Eyke Hüllermeier • Rudolf Kruse • Frank Hoffmann. ISBN 9783642140495 • 9783642140488. DOI 10.1007/978-3-642-14049-5

MODIFICATIONS/CHALLENGES

- The budget at our level was not made available until December 2015 which created problems in the management of expenses attributable to the project.

TABLE 1 (DATA ASSEMBLED DURING Y1 – CURRENT STATUS)

DB author	Excel file	Crop	Files received		Processed data	
			Main data	Weather data	Output1	Weather
Zebarth	CM	Barley & Potato				
	GHGB&CNT	Barley				
	HLB	Barley				
	ACD	Potato				
	Agrium	Potato				
	CR	Potato				
	DST	Potato				
	GAPS	Potato				
	GE	Potato				
	GHG	Potato				
	HLR&HLS	Potato				
	PQ	Potato				
	RG	Potato				
	SPLT	Potato				
	HLW	Wheat				
	HLWT	Wheat				
Schoenau	Jeff	Cereal				
Tenuta	Mario	Potato				
Drury	Drury	Corn				
Dyck	Dyck	Barley				
Mohr	Mohr	Potato				
	Mohr200306	Potato				
Parent	LEP	Potato				
SAGES	SAGES	Potato				
Cambouris	Cambouris	Potato				

Fully obtained

Partially obtained

Fully treated

Partially treated