Benchmarking the performance of a decision support system

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Abstract - A benchmarking survey was developed to measure the baseline performance of a decision support system (DSS) operated by the Production Estimates and Crop Assessment Division (PECAD) of the USDA Foreign Agricultural Service (FAS). The purpose of the survey was to collect essential performance indicators and metrics to be used in establishing the baseline, as well as in populating the matrices of a Defect Detection and Prevention (DDP) risk management tool. Based on the results of a previous PECAD characterization study, the survey focused on operational/analytic, organizational/management, and technical/information technology components of the PECAD's decision-making environment. The survey results allowed us to benchmark the various aspects of the DSS performance and establish a baseline, against which the enhancements to the DSS (e.g., integration of NASA's MODIS and TRMM data) would be measured. One purpose of this effort was to help promote the integration and use of NASA geospatial data, mission products, and/or science results in DSSs in partnership with their Federal owners.

Keywords: Decision Support Systems, MODIS, Benchmarking

INTRODUCTION

The United States Department of Agriculture's (USDA) Foreign Agricultural Service (FAS) Remote Sensing Program originated from the National Aeronautics and Space Administration (NASA) Large Area Crop Inventory Experiment (LACIE) and AGRISTARS Programs in the 1970s. The Production Estimates and Crop Assessment Division (PECAD) is the analytical unit within FAS and USDA for assessing global agricultural production and conditions that affect world food security. PECAD is intended to provide agricultural intelligence for global food security. PECAD's mission is "***to produce the most objective and accurate assessment of the global agricultural production outlook and the conditions affecting food security in the world"*** . The primary objective of PECAD is to target, collect, analyze, and disseminate timely, objective, useful, and cost-effective global crop condition and agricultural production information. PECAD has a long history of collecting market intelligence, promoting and projecting market imports and exports, and creating reliable production numbers for grains and oil seeds. As the premier source for monitoring global production of all crops of major economic importance, PECAD seeks to incorporate advanced scientific principles, methodologies, and a variety of geospatial information technologies to provide accurate, near real-time analyses of episodic weather events.

While PECAD has developed many value added products for use by crop assessment analysts over the last few years, much of the remote sensing methodology and crop models currently in use were developed in the 1970s. The Division aims to take the next step in fully exploiting current satellite data as well as to take full advantage of new sensors coming on line in both the near and long terms.

PECAD has developed extensive experience in crop yield estimation. However, errors in production estimates regularly occur due primarily to inaccurate estimates for crop area. Area calculations for major commodities such as small grains, corn, soybeans, oilseeds, and cotton can be measured using multi-spectral satellite imagery if time-series products are acquired in a timely manner.

NASA's Earth Observing System (EOS) has generated science results derived from its unique observational data that offer potential operational value for relevant applications. Similarly, the science models that are developed utilize these observations to predict or estimate future conditions. As the utility of satellite and other remotely sensed data increases, PECAD continues to explore the use of these new sensors, such as radar satellites to enable monitoring of crops in monsoon climates and MODIS multi-spectral satellites, which will greatly aid in developing spectral libraries for crop calendars, crop type identification, and crop stage.

FAS / PECAD SURVEY

PECAD analysts use a Decision Support System (DSS) that utilizes several different satellite data sources, input databases, climate data, crop models, and data extraction routines. PECAD relies on a convergence of evidence methodology that uses these multiple data and information sources to minimize risk of error and maximize reliability of estimates. Analyses utilize several EOS sensors either through direct analysis or as input into various crop models. Until recently, data from NASA (Landsat) and NOAA (AVHRR) have been the major remote sensing inputs to the process of generating agricultural assessments. PECAD desired to upgrade and enhance the DSS, and one element of this enhancement was to incorporate the Moderate Resolution Imaging Spectroradiometer (MODIS) data. Specifically, PECAD wanted to use MODIS Rapid Response data products that could be provided to the analysts and used in semi-real time, ideally next day. To efficiently integrate MODIS products, several preprocessing steps had to be made prior to data assimilation. Those steps included database design and development, staff training, and information system upgrades. To benchmark the impact of DSS enhancements, a number of tools and procedures were developed to collect data and define baseline, State 1, performance metrics and indicators.

The perceived benefits of PECAD's evolving DSS are: improved quality of crop assessment and production estimates and decisions, improved communication among its users, cost reduction, increased productivity, time savings, and improved customer and employee satisfaction. PECAD's DSS continues to improve in user-friendliness, and its capacity to conduct special analysis. PECAD's production estimates are considered to be more reliable and accurate than their "competition".

This paper describes the benchmarking process of the baseline performance measure of the PECAD DSS (State 1) by means of a multi-instrument survey conducted by a team of collaborators from the University of Missouri, University of Arizona, Jet Propulsion Laboratory, and Foreign Agricultural Service. Four questionnaires were developed by the team to provide more complete and consistent information about the characteristics of the PECAD DSS and aid in the initiation of a benchmarking process. The outcome of the benchmark is intended to measure performance improvements/changes within the DSS based on current status of NASA's science, data and technology integration in comparison with the a DSS that incorporates new NASA data, science and technology (e.g. MODIS and TRMM products).

Analysts', Management, and IT Questionnaires

It is important to recognize that a decision support tool operates within a decision making system that has a much broader environment than the technical realm. This realization has manifested itself with the development of enterprise architecture efforts whereby the entire system (performance measures, business mandates, service delivery, technical implementation, and data underpinnings) is examined to assess fit and alignment as well as success and productivity. It is within this conceptual structure that any NASA integration effort must be benchmarked to permit the assessment risk, probability of success, and operational hurdles that must be overcome – be they technical or organizational.

Thus the movement to an operational usage of NASA technologies (data, information, models) within an organization is not purely a technical issue. This research recognized that fact and as part of the benchmarking procedures included the questioning of not only the analysts but also the information technology staff that supported the application/integration as well as the managers of these staff under whose watch this integration was taking place. If either of these two additional elements were not prepared to support or did not understand the importance or relevance of the integration, it would fail – even if the application elements themselves were deemed useful.

These questionnaires were developed by sector (Analyst, Information Technology (IT), and Management) to provide more consistent and additional information about the current characteristics of the DSS of the FAS. These answers will aid in the set-up of a benchmarking process. The outcome of the benchmark is intended to show how investments from FAS and NASA changed the value or utility of the DSS. The benchmarking process used metrics that indicated performance measures and status of the current input of NASA's science, data and technology. These questionnaires were based on interviews and discussions that Wim van Leeuwen and Tim Haithcoat had with PECAD personnel in February, 2003.

Questions were asked of each sector regarding educational background and exposure to remote sensing and geographic information systems. The implication being that readiness of adoption is directly linked to exposure to the technologies being asked to adopt. Management had little exposure so great care is going to need to be exerted to make sure that the management knows and understands (in simple terms) the potential and impacts of the effort. Both the Analysts and IT sectors had some formal educational exposure but most (typically 75%) of their education came in the form of workshops, on-the-job, and self-study type forums. This shows a large need for continuing education so that the staff can understand and then appropriately apply the technologies being presented through this integration effort.

The value measure of the various information sources across these sectors is also revealing (Figure 1). While the Analysts and Managers seemed to be more in alignment, there is a large disconnect with the IT staff. This has implications in terms of the prioritization of integration efforts, standardization alignment, and future directions to be pursued. This disconnect can be tied back to the fact that the IT staff does not interact with much of these data sources that the analysts use (Figure 2). This has implications on knowledge management within the organization, future data mining possibilities as well as current data handling and interoperability issues, all of which can greatly impact an organization's ability to successfully integrate a new NASA data, model, or application stream.

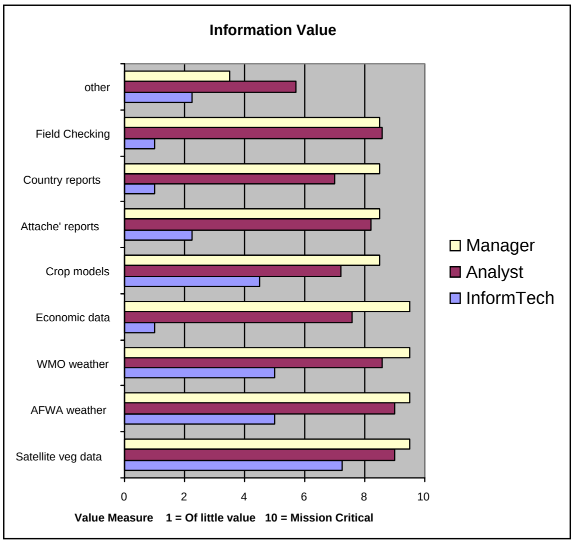

Figure 1: Information Value Comparison between sectors

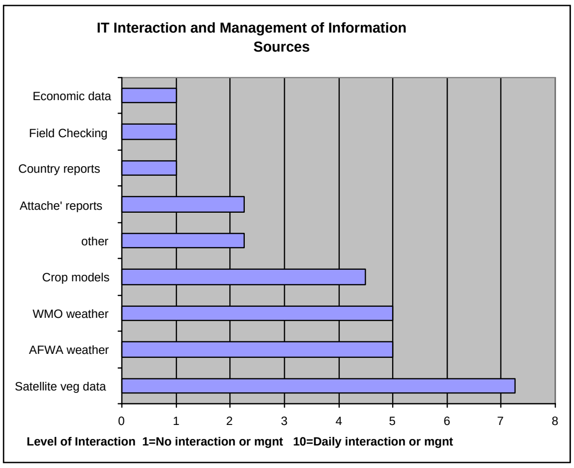

Figure 2: IT interaction with information sources

These IT issues, and many other examples derived from these surveys, have implications on not only the success of the integration effort, but also the ability to move it to operational mode, balancing implementation components, and successfully navigating changes in business processes and their prioritization.

These sectors also differed in their view of who they ultimately provide services to and those clientele's satisfaction with the outputs (decisions) from the PECAD group (Figure 3). The gaps reported and represented graphically provide necessary insight into how PECAD may need to adjust the organizational view of its mandate, as it will impact how responsive the sectors are to the various user communities, as well as alignment of satisfaction of the clientele with PECAD's mandates and goals.

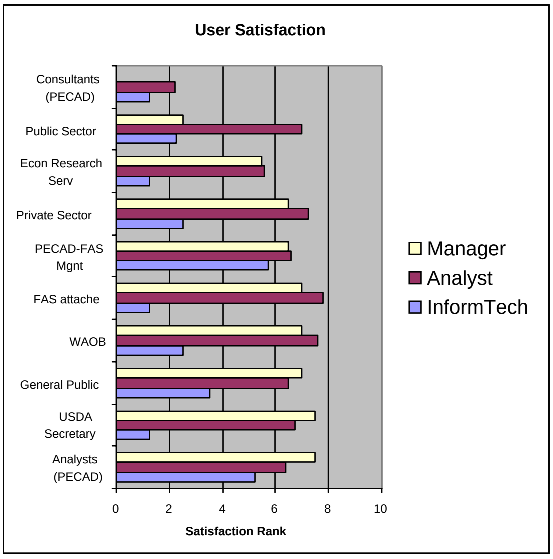

Figure 3: Sector-based views of user satisfaction with outputs of PECAD analysis.

The implications to the management sector include future direction choices, training availability, marketing and growth of the service side of the organization, and the direction and potential changes in the business processes and their prioritization across the FAS-PECAD group.

Finally, the Analyst's survey covered many areas related to the DSS and tools as well as the types of information used, their utility, and their importance. Programmatic implications discovered and benchmarked included the gaps between how important an information source was deemed and the current information's ability to meet that need (Figure 4).

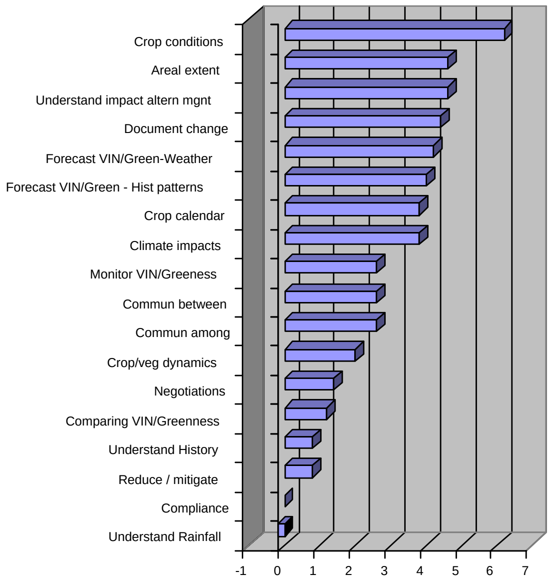

Figure 4: Gap between importance of need and current information's ability to meet that need.

These types of results provide the foundation for implementation and information discovery as well as programmatic planning, research, and future development.

DDP Questionnaire

One critical element of the benchmarking process and the assimilation methodology has been the incorporation of the Defect Detection and Prevention (DDP) software tool developed by JPL for addressing risk reduction in mission planning (Cornford et al., 2001). It provides a comprehensive and consistent framework for: 1) eliciting system requirements from the DSS owners and establishing their relative importance, 2) identifying risks to meeting those requirements and their relative impacts (including assimilation-induced risks), 3) determining the degree to which risks can be mitigated (requirements satisfied) through the incorporation of alternative solutions, and 4) developing optimal solution sets. This approach incorporates a proven tool to assess performance before and after the assimilation activity. Moreover, through its comprehensive approach, DDP allows to capture and evaluate the more fundamental changes in decision making that would be achieved by altering the system rather than simply improving data quality. The methodology that the DDP application is based upon is contained in a document, *Assimilation of NASA Earth Science Results and Data in National Decision Support Systems: A Guidebook*. (Kaupp et al., 2003).

The DDP process begins with identification of three categories: Objectives (where we want to be), Risks (what could get in the way), and Mitigations (how we will get there). The DDP procedure is then applied to prioritize the Risks versus the Objectives and to evaluate the effect of various Mitigation combinations at preventing the occurrence of these Risks resulting in a balanced risk profile. Three steps of the DDP process include: 1) Development of the Impact (Objectives versus Risks) matrix; 2) Development of the Effectiveness (Mitigations versus Risks) matrix; and 3) Selection of Mitigations to balance the residual risk.

The purpose of the DDP questionnaire was to provide quantitative input to the software tool, namely, numeric data for populating the Impact and Effectiveness matrices. Based on the information collected previously through one-on-one and group interviews with the PECAD personnel, an on-line questionnaire tool was developed consisting of thirty seven questions. Ten PECAD analysts were asked to complete the on-line form by providing one of the predetermined responses None (0.1), Low (1), Medium (5), High (9), or Unknown (not accounted). The numeric values in the parenthesis were used to find the average by using the geometric mean formula. The results were input into the two matrices, shown in Figure 5 and Figure 6.

Geomean values in the range of 7-9 were considered as denoting high degree of impact/effectiveness (color-coded red), 4-6 – medium (yellow), and 1-3 – low (green). Color coding allows for a quick visualization of patterns in both matrices. For example, the Impact matrix shows that two of the potential Risks (Inadequate accuracy/reliability of weather data and Lack of baseline or historical information) have the highest degree of impact on the attainment of Objectives. Indeed, the sums of respective columns (60.09 and 56.04) are far ahead of the other Risk elements.

Geomean: High=9; Medium=5; Low=1; None=0.1

Impact Matrix: What is the impact of the risks on the objectives?

Objectives			Lack of continuous access to field-level multispectral observations (e.g. Landsat-like)	Lack of continuous access to national level multispectral observations (e.g. AVHRR-like)	RS data receipt is not timely	Inadequate accuracy/reliability of weather data	Significant obstacles to operational use of RS within PECAD	Lack of baseline or historical information for comparative RS analysis	Inadequate crop models
Provide accurate monthly production numbers by commodity and country	Crop area estimates	Early in crop growing season	2.27	2.12	1.89	4.86		6.24	2.14
		Late in crop growing season	3.10	1.98	1.68	4.10		8.16	2.29
	Crop yield estimates	Pre-planting	0.40	0.73	0.22	2.61		1.22	1.14
		Planting	1.90	2.76	0.89	4.66		2.92	3.23
		Vegetative growth	5.16	5.10	6.08	8.49		7.00	7.61
		Reproductive	7.11	5.41	9.00	8.49		9.00	6.58
		Grain filling	4.05	3.49	4.65	8.43		5.66	6.58
Provide the supporting evidence at lock-up			3.29	2.77	4.10	5.11	7.61	7.61	7.00
Provide automated analysis products to external customers			1.87	1.70	1.96	6.35	6.05	2.67	3.18
Have an ad hoc analysis capability			6.71	4.11	8.43	7.00	8.28	5.56	4.42
			35.87	30.17	38.89	60.09	21.93	56.04	44.14
Color coding:									2/16/2005
High		7-9							
Medium		4-6							
Low		1-3							
Negl.		<1							

Figure 5. Impact matrix (Objectives versus Risks)

Geomean: High=9; Medium=5; Low=1; None=0.1

Effectiveness Matrix: How effective are the mitigations against the risks?

Mitigations			Lack of continuous access to field-level multispectral observations (e.g. Landsat-like)	Lack of continuous access to national level multispectral observations (e.g. AVHRR-like)	RS data receipt is not timely	Inadequate accuracy/reliability of weather data	Significant obstacles to operational use of RS within PECAD	Lack of baseline or historical information for comparative RS analysis	Inadequate crop models	
Land remote sensing	MODIS products	MODIS Rapid Response Products	5.56	8.28	9.00	2.17	2.72	1.20	0.98	29.91
		MODIS Vegetation index product (NDVI and EVI)	4.70	9.00	4.80	2.97	4.65	1.14	1.52	28.79
		Surface reflectance	3.56	7.40	5.66	3.22	3.22	1.68	1.85	26.60
		Crop Mask	2.92	2.24	1.89	1.71	2.47	1.14	1.42	13.78
	ASTER		0.32	0.71	0.71	0.95	0.95	0.71	0.95	5.28
	SPOT-VEGETATION product		2.53	3.68	4.35	2.47	1.14	1.85	1.30	17.31
	Reservoir heights (Topex/Jason)		0.47	0.47	0.51	0.81	0.51	0.47	0.64	3.88
	NOAA/SSMI (surface wetness)		0.98	0.98	1.28	3.17	1.68	2.92	0.97	11.99
FAS attache ground truth			6.43	5.56	5.11	5.11	2.14	3.18	2.32	29.85
Multiple sources of atmospheric remote sensing and weather data			1.52	1.99	1.99	3.49	0.88	0.61	1.14	11.63
External data sources (incl. Reuters, economic, internet, etc.)			5.56	5.56	4.42	4.06	5.56	2.95	2.67	30.78
PECAD-obtained ground truth in field			5.56	3.73	4.06	5.11	4.06	5.13	3.92	31.58
Having a trained analyst for each region			6.43	6.43	5.11	7.00	5.13	7.00	5.11	42.21
Current suite of tools for early warning of crop conditions			6.08	6.08	8.00	8.00	6.71	7.77	6.71	49.35
Availability of a DBMS (continuously being maintained and extended)	CADRE DBMS		2.08	2.08	3.56	9.00	4.33	4.33	7.40	32.77
	Crop Explorer's DBMS		3.56	9.00	6.71	0.95	3.00	6.71	9.00	38.92
Improved crop yield and soil moisture models	Crop stage models		6.71	6.71	6.71	5.00	5.00	6.71	5.00	41.83
	Crop yield models		5.00	6.71	5.00	5.00	6.71	2.24	6.71	37.36
	Soil moisture model		5.00	2.24	2.24	5.00	5.00	6.71	6.71	32.89
Adopting new technology			6.71	3.00	6.71	9.00	6.71	6.71	3.00	41.83
			81.67	91.84	87.81	84.19	72.55	71.14	69.33	
Color coding:										
High		7-9								
Medium		4-6								
Low		1-3								
Negl.		<1								

Figure 6. Effectiveness matrix (Mitigations versus Risks)

The values obtained through the questionnaire were utilized in the DDP software tool to evaluate the effectiveness of various Mitigation options against the potential Risks, with quantified attainment of Objectives being the most important benchmarking indicator.

REFERENCES

Cornford S.L, Feather M.S., Hicks K.A., DDP – A Tool for Life-Cycle Risk Management, *2001 IEEE Aerospace Conference Proceedings*, Big Sky, Montana, January 2001.

Kaupp, V., Hutchinson C., Drake S., W. van Leeuwen, and D. Tralli, Assimilation of NASA Earth Science Results and Data in National Decision Support Systems: A Guidebook, NAG-5 -12482 and NAG-5-12484, April 2003.