<u>דו״ח מסכם – מחקר במימון המדען הראשי של משרד החקלאות</u>

דו״ח לתוכנית מחקר 304-0450-11

ניטור מתקדם של עצי פרי – איך להתמודד עם שונות בגורמים סביבתיים?

Advanced monitoring of tree crops – how to cope with variability in environmental factors?

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אמוץ חצרוני, הנדסה חקלאית, מינהל המחקר החקלאי, מכון וולקני

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Amots Hetzroni, ARO, Volcani Center

2013

הממצאים בדו״ח זה הינם תוצאות ניסויים.

הניסויים לא מהווים המלצות לחקלאים

חתימת החוקר

פרסומים

Peeters, A., Ben-Gal, A., Kathner, J., Unlu, M., Kanber, R., Hetzroni, A., Gebbers, R., Zude, M., (submitted, 2013), A methodology for defining management zones in orchards based on spatial statistical analysis, submitted to: *Precision Agriculture*.

Peeters, A, **Ben-Gal, A**, Hetzroni, A and Zude M. 2012. Developing a GIS-based spatial decision support system for automated tree crop management to optimize irrigation inputs. International Environmental Modelling and Software Society (iEMSs). 2012 International Congress on Environmental Modelling and Software Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany. R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.) http://www.iemss.org/society/index.php/iemss-2012-proceedings.

Hetzroni, A., **Peeters, A., Ben-Gal, A. 2012. Towards precision management of orchards: using automated monitoring to build a GIS-based spatial decision support system. International Conference of Agricultural Engineering. CIGR-Ageng2012, Valencia, Spain July 8-12, 2012.

תקציר

מטרת הפרויקט היא לשלב מומחיות על רובוטיקה ואוטומציה בן לאומי על מנת לייעל משטרי ניהול במטעים ופרדסים. לעשות זאת נבחנים שיטות שונות של ניטור ברמות שונות ושל פרמטרים שונים. הניטור כולל מהרמה של פרי בודד עד לרמה של שטח שלם. הנתונים עוברים ניתוח לפי מודלים של יחסים בין קרקע-מים-צמח-אטמוספרה מוניסטיים וניתוח סטטיסטי מרחבי.
מטרות של הפרויקט:
-אינטגרציה של ידע על בסיס העץ והפרי בהשפעת השקיה
-ניטור אוטומטי של גידול, יבול ופרי של פרי הדר (אשכולית) ושל שזיף בשימוש שיטת ה multisensing, ניתוח בGIS וניתוח מרחבי (spatial analysis).
-פיתוח של איסוף נתונים אוטומטי לגבי עצים ופירות (רובוטיקה)
-מיפוי מקומי עם ידע ברמה של העץ להטיב מערכות ההשקיה
הפרויקט מנוהל על ידי חוקרת גרמניה ויש בו שוטפים טורקיים, איטלקיים, שוויצריים, אנגליים, יווניים, וספרדיים. התפקיד של הקבוצה שלנו מתמקד בארגון וניתוח הנתונים ופיתוח והפעלתם של מודלים.
בשנה הראשונה של הפרויקט התבצע ניסוי שדה בטורקיה. התקדמנו בפיתוח מודל סטטיסטי מרחבי שיאפשר היווצרות של מפות בהן אזורי ניהול (management zones) ומודל לניהול מדויקת במטע.
בשנה הנייה התבצע ניסוי שדה בגרמניה. הופעלנו על נתוני הניסוי את המודל לייצר מפות ניהול והשתמשנו בנתונים להדגים בחירה של מערכת תומכת קבלת החלטות מרחבית אוטומטית (Automated spatial decision support system) . נשלח מאמר לג'ורנל Precision Agriculture, מאמרים השני ושלישי בהכנה.

1. Project data

1.1. Project title

3D-Mosaic

1.2. WP- and Subtask-Numbers (see consortium contract for individual contributions)

WP 4.1; WP 5.2; WP 6.1, 6.2, 6.3

1.3. Name of the contact person

Dr. Alon Ben-Gal

1.4. National contract number for funding by NCP

304 0450 11

2. Content

2.1. Referring to the project application, the current progress is …

- X as planned
- ☐ faster as planned
- ☐ behind the plan (short description under 2.4)

2.2. Project objectives: mark the status of each relevant subtask.

WP1. Platform (WP leader: Griepentrog, UniHoh, Germany; AUTH; Sintéleia, ZHAW, UniKas)

Adaptation of an autonomous platform for transport of the mobile sensors and for implementation of efficient monitoring strategies

	finalized	under progress	not started
1.1 Autonomous Platform (UniHoh, AUTH)	☐	☐	☐
1.2 Sampling Strategy (UniHoh)	☐	☐	☐
1.3 Data Handling and Management (AUTH, ZHAW, Sintéleia)	☐	☐	☐

WP2. Vision system (WP leader: Seatovic, ZHAW, Switzerland; UniKas, ART)

Development of a mobile image analysis system for detection of trees and fruits

2.1 Leaf Area Index (LAI) (ZHAW, ART, UniKas)	☐	☐	☐
2.2 Fruit Development (ZHAW, ART, UniKas)	☐	☐	☐

WP3. Fruit information (WP leader: Torricelli, PoliMi, Italy; Sintéleia, AUTH, ATB)

Development of mobile fruit sensors for non-invasive fruit quality determination on the tree

	finalized	under progress	not started
3.1 Physical Calibration Correction (PoliMi, ATB, Sintéleia)	☐	☐	☐
3.2 Emerging Fruit Sensors (ATB, PoliMi, Sintéleia)	☐	☐	☐

3.3 Fruit Canopy Sensor (Sintéleia, AUTH, PoliMi, ATB)	☐	☐	☐

<u>WP4. Field tests</u> (WP leader: Gebbers, ATB, Germany; CU, AUTH, ARO, all)

Field trials for testing the system and data acquisition

4.1 Acquisition of Soil, Climate, and Plant Data at the Test Sites in Turkey and Germany during the Season (CU, ATB, ARO)	X	☐	☐
4.2 Field Trials with Autonomous Monitoring and Plant-Fruit Readings for Sensor Reference (ATB, CU, AUTH, all)	X	☐	☐

<u>WP5. GIS</u> (WP leader: Espinosa, Versas, Spain; AUTH, CU, ATB, UniHoh, ARO, all)

Geographical information system for 3D data management

5.1 GIS Data Management (Versas, AUTH, UniHoh, CU, ATB)	☐	☐	☐
5.2 GIS Decision Support System (Versas, ARO, AUTH)	X	☐	☐

<u>WP6. DSS for orchard irrigation</u> (WP leader: Ben-Gal, ARO, Israel; CU, ATB, Versas, AUTH)

Development of a decision support system to generate management maps

6.1 Management Zones (ATB, ARO, CU, Versas)	X	☐	☐
6.2 Soil-Plant Data Assessment (ARO)	X	☐	☐
6.3 DSS (ARO, Versas, CU, ATB)	X	☐	☐

2.3. Deliverables sorted by expected point of achievement: mark the deliverables achieved

D2.1.1: Definition of interfaces and coordination of the autonomous platform (month 4)	☐
D5.1.1: GIS data management SRS (month 5)	☐
D5.1.2: GIS data management SAS (month 6)	☐
D2.2.1: Field calibration for fruit detection (month 6-9)	☐
D1.1.1: Platform ready for orchard use (month 9)	☐
D1.3.1: Protocols and hardware for data transmission (month 9)	☐
D2.1.2: Semi-automated system for the first field trial (month 9)	☐
D2.1.4: Software for automated spatial coordinate calculation (month 9)	☐
D3.1.1: Advanced physical methods for field readings (month 9)	☐
D3.1.2: Tissue phantoms (month 9)	☐
D3.2.1: Protocols for advanced fruit sensors in citrus (month 9)	☐
D3.3.1: Fruit canopy sensors (month 9)	☐
D5.1.3: Software (first beta test) (month 9)	☐
D5.1.4: GIS data management STS and test results (month 10)	☐
D5.1.5: Documentation and manuals (month 11)	☐
D5.1.6: Operational GIS data management platform (month 11)	☐
D1.2.1: Preliminary fruit prediction models ready (yield and selected fruit properties) (month 12)	☐
D4.1.1: Field trial 1 test-site, objects and data (months 12, 20)	☐
D4.2.1: Evaluation of performance in field trial 1 (month 12)	☐

D6.1.1 Management map considering field trial 1 (month 17) ☐
D1.3.2: Optimized protocols and hardware for data transmission (month 18) ☐
D2.1.3: Platform with all spatial detection units with fixed spatial arrangement (month 18) ☐
D2.2.2: Development of algorithms for fruit detection (month 18) ☐
D3.1.3: Advanced physical calibration methods (month 18) ☐
D3.2.2: Protocols for advanced fruit sensors in (month 18) ☐
D3.3.2: Optimized fruit canopy sensors (month 18) ☐
D4.1.2: Field trial 2 test-site, objects and data (month 18) ☐
D6.2.1: Model and protocol considering field trial 1 (month 18) ☐
D6.3.1: Irrigation map and protocol considering field trial 1 (month 18) ☐
D4.2.2: Evaluation of performance in field trial 2 (month 20) ☐
D5.2.1: SRS and SAS Update (month 20) ☐
D1.2.2: Improved fruit prediction models ready (yield and selected fruit properties) (month 22) ☐
D6.1.2: Management map considering field trial 2 (month 22) ☐
D6.2.2: Model and protocol considering field trial 2 (month 22) ☐
D1.1.2: Scientific presentation ready for submission ('Robotic data acquisition of sensor data in fruit orchards') (month 24) ☐
D5.2.2: GIS DSS platform (month 24) ☐
D5.2.3: Documentation update (month 24) ☐
D6.3.2: Irrigation map and protocol considering field trial 2 (month 24) ☐

2.4. Which activities or analysis were done in the final half year of the project? Please make an abstract of your project's activities, e.g. the methods, experiments, results and discussions – sort by subtasks (max 2 pages).

1. Objective:
   Develop a GIS-based Decision Support System (DSS) for precision management of tree crops to optimize orchard management.
2. Intermediate Objectives:
   - Recognize statistically significant correlations between fruit and plant variables and between independent variables such as irrigation schemes and soil properties.
   - Integrate the statistical analysis into practical farm applications by developing different management scenarios (output: site-specific management and irrigation maps).
   - Develop future scenarios based on the management and irrigation maps and consequently develop a model for simulating (predicting) yield and fruit properties.
   - Based on the above develop a Spatial Decision Support System (sDSS) for managing orchards in terms of irrigation efficiency.
   - Use the data from the second field trial (Potsdam) to illustrate example for DSS choice of managment zones based on GIS spatial statistics.

3. Abstract of activities and accomplishments

Subtasks – DSS and management zones field trial 1

Introduction:

Management zones partition agricultural fields into sub-units which exhibit homogeneity in yield-defining environmental or plant parameters. Recent methods for defining management zones make use of algorithms such as fuzzy k-means clustering. These partition data observations into clusters based on different similarity methods and often do not account for the spatial neighbourhood. Spatial clustering methods, based on spatial statistics, include location of objects and spatial relationships and account for spatial heterogeneity. Existing clustering methods have been developed mainly for arable crops and not for individual trees in orchards. We present a comprehensive spatial clustering methodology for defining management zones in orchards based on data from individual trees.

Material and methods:

A section of 207 cv Rio Red grapefruit (Citrus paradisi) trees located in an approximately a 4 ha orchard near the city of Adana, Turkey (35o22'55"E, 37o1'24"N) was monitored in 2011-2012. A set of spatial statistical methods includeing, in particular, the Getis-Ord Gi* statistic (Gi*) was employed for defining management zones. The Gi* statistic evaluates the degree of spatial autocorrelation over a study area on a point-based scale by indicating the degree to which each feature is surrounded by features with similarly high or low values within a specified distance. Statistically significant spatial clusters were used for delineating management zones. The method was tested regarding apparent electrical conductivity of the soil (ECa) and tree trunk circumference data.

Results:

Yield data was used to evaluate the method's accuracy. To test whether clustering of tree trunk circumference and ECa values could predict clustering of yield a one-way ANOVA test was applied. The sampled trees were divided into groups based on the output management zones. The dependent variable was yield variation (represented by its clustering intensity) and the independent variables were the management zones as delineated by ECa and tree trunk circumference valuess. The objective was to evaluate whether the group means of the dependent variable (yield) differed significantly among the groups of management zones. Results demonstrated that while trunk circumference values were a valid parameter for predicting yield variations, ECa values were not a sufficient indicator for yield prediction and could not therefore serve as a unique parameter for defining management zones in the orchard.

Conclusions:

We demonstrate that point-based spatial-clustering methods and, in particular, the Gi* statistic represent a valid method for delineating management zones. However, since different parameters result in different management zones, it is important to first recognize the parameters that most influence yield variability and to develop the zones accordingly. As a method based on inferential spatial statistics, probabilities are assigned to management decisions. This supports reliable, informed decisions to advance sustainable and optimal management of orchards.

Subtasks – DSS and management zones field trial 2 The procedure described above and applied on field trial 1 is ucrrently being repeated for data from field trial 2. This will further be used to demonstrate development of an SDSS computer-based routine to evaluate the effect of different future scenarios by combining the GIS with management zones DSS. Plant and environmental data was collected for a plum orchard near Potsdam, Germany during August 2012. Developed methodology is currently being applied to data to recognize spatial variability, delineate management zones and quantify relations between parameters. Under process is: Application of a spatial correlation analysis i.e. a geographically weighted regression (GWR) using the data collected in field trial II to recognize the parameters that most influence and/or represent yield variability. Addition of simulated values to parameters based on future management scenarios and apply GWR to simulate future output management zones. Automation of the method to create a decision support system that will generate management zones based on future scenarios.

3.1. If problems appeared in the context of your project, please describe them here and make clear the apparent consequences for the final outcome of the project.

3.2. Deliverables of your project work (check list under 2.3 for your relevant deliverables). Please use the given structure.

1. D6.1.1 Management map considering field trial 1: D6.2.1: Model and protocol considering field trial 1

   1.1 Protocol and model for creating management map for field trial 1 was developed and published:

   1.2 Describe the final state of the product: Submitted publication and management zones map sent to partners (Versas) for use in commercial applications.

   1.3 Point out its impact (to scientific community, growers, industry, other stakeholders): Novel methodology for robust decision making promoting precision management of orchards.

2. D6.1.2: Management map considering field trial 2. Model and protocol considering field trial

   2.1 Protocol and model for creating SDSS for developing management zones based on robust spatial statistics from spatial data was developed for field trial 2. The publishing of this is currently in process and will be distributed to all partners and to Versas for application in commercial practices.

3. D6.3.1: Irrigation map and protocol considering field trial 1. D6.3.2: Irrigation map and protocol considering field trial 2

   Irrigation maps were not found to be relevant or practical in either of the field cases. Instead of "irrigation" maps, we have developed "management" maps to aid growers in pruning, thinning, and harvesting their trees in order to maximize returns by optimizing fruit yield and quality in orchards. With the protocols developed growers can chose end characteristics that are most important and recognize spatial patterns of variables influencing them. Spatially significant patterns of the yield or quality influencing variables will enable precision management of trees to promote orchard performance and profit.

Impact (to scientific community, growers, industry, other stakeholders):

We expect the new processes for building decision making tools described above to have substantial impact on managers of orchards (directly) and on those in the industry who are involved in data gathering (indirectly). Until now, even when large amounts of high resolution spatial-temporal data were available in orchards, little was done with them. Our accomplishments open opportunities for vast advancements in precision management of orchards based on such data that we expect to be soon in coming and expect to have nearly unlimited economic value.

4. Advance

4.1. Please list scientific publications of last half year of the project in detail here. Please list oral as well as written presentations as well as communication with the media and public (TV, fair trade, ..).

Peeters, A., Ben-Gal, A., Kathner, J., Unlu, M., Kanber, R., Hetzroni, A., Gebbers, R., Zude, M., (submitted, 2013), A methodology for defining management zones in orchards based on spatial statistical analysis, submitted to: *Precision Agriculture*.

4.2. Please describe the project's results regarding further publication potential.

We expect at least 2 additional publications, the first regarding LiDAR data processing and the second describing the total methodology for SDSS for choosing management zones in orchards.

Peeters, A., Seelbeck, J., Jaeger-Hansen, C., Hetzroni, A., Zude, M., Ben-Gal, A., Extracting tree parameters using laser scanning (LiDAR) for precision management of orchards

Peeters, A et al.… A spatial decision support system (SDSS) for precision management of orchards

5. Cross-border cooperation

Please describe briefly, in which typical "networking activities" you were involved and explain what positive and/or negative experiences you have experienced in the cross-network collaboration and cooperation with partners.

Jana Kathner was hosted by ARO to work on data and publishing in April 2013.

Alon Ben-Gal will attend the EFITA conference in June 2013 to present the ARO group's findings and to hold summary meetings with all 3D-MOSAIC partners.

We are in continuous contact with researchers from ATB and Versas regarding data flow and treatment. We continue to work with all the groups doing imaging concerning novel statistical treatment of LiDAR data.

סיכום עם שאלות מנחות

מטרות המחקר תוך התייחסות לתוכנית העבודה.
תמיכה של חקלאות מדויקת במטעים על ידי פיתוח של סנסורים לניטור ושיטות ניתוח. בניית כלים תומכי
החלטות בשימוש סטטיסטיקה מרחבית
עיקרי התוצאות.
בוצעו מדידות אינטנסיביות בפרדס אשכוליות בטורקיה ובמטע שזיפים בגרמניה. נאספו נתונים רבים.
וסטטיסטיקה מרחבית. נבנו כלים לבחירתם של אזורי ניהול מפרדס ופותח שיטה להיווצר מערכת מרחבית
תומכת החלטות .
מסקנות מדעיות וההשלכות לגבי יישום המחקר והמשכו. האם הושגו מטרות המחקר לתקופת הדו״ח?
מטרות של הפרויקט הוסגו. פוטנציאל גדול למיפוי לפי גודל עץ מנתוני LiDar
בעיות שנותרו לפתרון ו/או שינויים (טכנולוגיים, שיווקיים ואחרים) שחלו במהלך העבודה; התייחסות המשך
הפצת הידע שנוצר בתקופת הדו״ח: **פרסומים בכתב** - <u>ציטט</u> ביבליוגרפי כמקובל בפרסום מאמר מדעי;
התקדמות של הצוות הישראלי בפרויקט פורסמה ב2כנסים באירופה:
Peeters, A., Ben-Gal, A., Kathner, J., Unlu, M., Kanber, R., Hetzroni, A., Gebbers, R., Zude, M., (submitted, 2013), A methodology for defining management zones in orchards based on spatial statistical analysis, submitted to: Precision Agriculture.
Peeters, A, **Ben-Gal, A**, Hetzroni, A and Zude M. 2012. Developing a GIS-based spatial decision support system for automated tree crop management to optimize irrigation inputs. International Environmental Modelling and Software Society (iEMSs). 2012 International Congress on Environmental Modelling and Software Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany. R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.) http://www.iemss.org/society/index.php/iemss-2012-proceedings.
Hetzroni, A., **Peeters, A., Ben-Gal, A. 2012. Towards precision management of orchards: using automated monitoring to build a GIS-based spatial decision support system. International Conference of Agricultural Engineering. CIGR-Ageng2012, Valencia, Spain July 8-12, 2012.
פרסום הדו״ח: אני ממליץ לפרסם את הדו״ח: (סמן אחת מהאופציות)
➢ללא הגבלה (בספריות ובאינטרנט) X
➢חסוי – לא לפרסום: יש לצרך אישור ומידע ממוסד המחקר
האם בכוונתך להגיש תוכנית המשך בתום תקופת המחקר הנוכחי? לא -

*יש לענות על שאלה זו רק בדו״ח שנה ראשונה במחקר שאושר לשנתיים, או בדו״ח שנה שניה במחקר שאושר לשלוש שנים