

ההתפתחות העתידית של הנוף בשטחים הפתוחים בישראל: מודל לחיזוי הסוקצסיה של צומח מעוצה בנופים ים-תיכוניים כתוצאה משילוב בין יערות נטועים וחורש טבעי

**Development of the Landscapes of Open Spaces in Israel in the Future:
Modeling the succession of woody vegetation in Mediterranean landscapes as a
result of the integration among man-made forests and natural woodlands**

Final report: March 2008 – September 2009

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Abstract

We report here on preliminary work and initial analysis in our project dealing with colonization by the Mediterranean trees Aleppo pine (*Pinus halepensis* Mill.) and common oak (*Quercus calliprinos* Web.), and their effects on open landscapes of the Mediterranean region in Israel. During the research and grant periods we engaged in the following tasks: (1) a visit in Israel of our collaborator in this research - Dr. C. D. Canham, an expert forest researcher from the Carry Institute of Ecosystem Science (New York, USA); (2) travel and joint work of Efrat Sheffer and Dr. Canham in his laboratory, and participation in an international course to study the implementation of maximum likelihood modeling methods in ecology; (3) purchase of a powerful computer to perform data analysis and modeling; (4) initiating the analysis of some of the first part of field collected data in a second period of work of Efrat Sheffer with Dr. Canham at Carry institute; and (5) purchase of additional modeling and computational tools for data analyses. In the grant period we have achieved great progress in this study. The interaction with Dr. Canham during our meetings in Israel and abroad set the ground to a promising methodology to study the dynamics of pine and oak colonization and ecosystem dynamics arising in these complex mixed vegetation systems. Our research utilizes novel methods of hypotheses testing through statistical inverse modeling, thus allowing us to provide scientists and managers with

better knowledge and the ability to predict trends in this slow vegetation dynamics within two to three years of research.

1. Dr. C. D. Canham visit in Israel

In March, 2008 we invited Dr. Canham to visit Israel for a week and become familiar with the local forest systems. During this intensive work week we presented and discussed different aspects of natural and anthropogenic open landscapes in Israel and met with forest and land managers from different regions and departments in KKL.

Dr. Canham's visit in Israel was indispensable for this collaborative research. On the one hand, he got familiar with our Mediterranean study systems and was thus able to better understand some of the complexities that accompany research in open landscapes in the region in Israel. On the other side, traveling with Dr. Canham in these systems and meeting forest managers in his presence highlighted many aspects of ecology, forestry and management that we were not previously familiar with. The combination of researchers in our team, our meetings with KKL experts and the diversity of forest and natural vegetation phenomena we explored in this visit opened many new issues for discussion and topics for research. As a consequence we moved our research focus towards searching for a phenomenological model that describes colonization dynamics in changing landscapes. This decision was also based on our understanding of the interests presented to us by KKL managers, i.e. understanding tree dynamics at the stand and landscape levels, rather than exploring individual level processes of seed and seedling establishment in detail.

2. Developing the research plan and the skills necessary to implement it

A. Complete and detailed research plan Our research aims to assess how colonization dynamics are controlled by (1) the spatial configuration of the landscape and its effect on colonization pressure, and (2) local environmental conditions acting as resistance factors that control in-situ colonization. In addition, we examine how colonization of natural Mediterranean vegetation by Aleppo pine and the development of common oak inside Aleppo pine forests affect soil properties and ecosystem processes (i.e. litter decomposition and soil nutrient cycling). Understanding the ways by which integration of pine and oak into one ecosystem affect ecosystem dynamics/properties is important as a first step to assess whether colonization by these

species can lead to modification of ecosystem function that, in turn, produces feedbacks that drive further changes in community composition. This research program was developed to its details with the collaboration of Prof. Avi Perevolotsky and Dr. Canham, with enormous advancement and contribution during Efrat's work with Dr. Canham at IES. The research plan that was developed is composed of field surveys and data analysis to produce models for these different dynamics.

B. Field surveys intended to measure dynamical processes of colonization by each of the studied species – pines and oaks. We developed the methodology and details of our field surveys during Efrat's visit at IES. These surveys aim to measure the spatial distribution of colonizing individuals in samples throughout the Mediterranean area in Israel, in a variety of habitat conditions.

3. Analysis of field survey data

The analysis of pine and oak colonization and how these processes alter Mediterranean ecosystems is carried out in the framework of inverse modeling. Inverse modeling methods are very powerful tools to describe and analyze phenomenological processes, to compare alternative models (as working hypotheses) and find the most likely model parameters. Inverse modeling is becoming a powerful tool for ecological studies, especially for questions that can not be investigated using traditional hypothesis testing manipulation experiments. Nevertheless, this approach is barely known and not currently in practice by Israeli researchers.

A. Preparing the background to conduct research using inverse modeling and likelihood approaches. In the first visit of Efrat Sheffer at NY we conducted the following efforts to prepare the background to make this research possible:

- 1) **Likelihood Methods in Ecology course** – in June 2008 Efrat Sheffer participated in a course to study the use of likelihood methods in ecology. This intensive, 2-week course covered the concepts, theories, and application of likelihood methods as a comprehensive framework for analysis of ecological data and for testing alternate hypotheses in the context of model comparison. The course was offered for graduate students, postdocs, and faculty in ecology or related fields. The course was offered by the Cary Institute of Ecosystem Studies and Columbia University, and taught by Dr. Charles Canham (Cary Institute) and Dr. Maria Uriarte (Columbia University). In the course Efrat also learned the use of R program, a free, open-source platform for statistical

computing (<http://www.r-project.org/>) and programming tools designed for data analysis and maximum likelihood estimation using different optimization algorithms.

- 2) **Writing programs for data analysis** - Following course exercises Efrat developed preliminary computer programs that for research data analysis: (1) preliminary codes to examine the possibility to perform such analyses of the data that was planned to be gathered in field surveys; (2) mathematical models that describe integrated succession of man-made pine forests and natural oak woodlands as a process of reciprocal colonization of Aleppo pine trees in natural Mediterranean systems and Oak colonization in planted pine forests; and (3) computer algorithms to find models parameters and perform model comparison in a Likelihood framework.
- 3) **Development of mathematical models** - we developed these mathematical models and a detailed research plan for field surveys while working with Dr. Canham at the Carry Institute, in June 2008. We developed two models for reciprocal colonization processes of pines and oaks in Mediterranean regions of Israel. We designed and specified all components of the model, i.e. processes that determine colonization potential and limitations, and suggested mathematical representations for these processes. Finally, we planned field studies in which we will gather data required to estimate critical parameters.

B. Conducting inverse modeling and likelihood analyses of field data. A second working period of Efrat with Dr. Canham at Carry institute took place in September 2009. At this stage we had already collected a sufficiently large dataset (470 samples) to study the process of pine colonization in open Mediterranean landscapes covered by maquis, garigue or batha. Efrat's second visit at Carry Institute, was devoted to the analysis of data of pine colonization of natural vegetation, and collected in the field throughout October 2008 – July 2009. We developed computer codes to read in field data and background information of the spatial distribution of pine trees surrounding our field samples, as represented in GIS maps/layers that were constructed from a variety of sources. In this visit we composed the basic model codes and began running search algorithms written to search for the best model, i.e. a model that is most suit to describe the process and the values of the parameters in this

model that provide a best fit. Likelihood and information theory tools were used to test model fit. Although we did not finish all analyses in this relatively short visit, the time spent in close work with Dr. Canham allowed Efrat to learn how to use these tools and continue analyzing this data and our next results in Israel independently. In the following months we will continue with these analyses looking for results that will explain the process of pine colonization.

4. Modeling tools

We purchased a strong laptop computer with some basic software, to be used for the collection and analysis of all the data in this project. Arc-GIS software for this computer was provided by Dr. Canham. Data analysis using likelihood methods will be done mostly using the R statistical program. R is a powerful programming language/environment that is particularly suited to statistical analysis and it is free for download, thus becoming a leading tool for statistical programming for scientists around the world.

Modeling pine colonization of natural landscapes requires strong computing power because the models we are searching for analyzes how all pine seed sources in a very large spatial zone (up to 2500 m radius) surrounding each of our samples (almost 500) affects colonization. To search for the most parsimonious model we use a search algorithm that explores all possible parameters for each alternative hypothesis. The search algorithm runs for tens of thousands of iterations and the number of iterations increases with model complexity. Running these search algorithms is a slow process that may take weeks or months to complete. Thus, performing these analyses will require a strong computer with a large bulk of free memory space to do all this calculations. With the remains of this grant we aim to purchase a strong desktop computer to use for running model analyses.

5. Future plans

Based on our work in 2008-2009 we plan on continuing this research. The goals of our future work are: *(i)* to compose a full explanatory model of pine colonization in open Mediterranean landscape, *(ii)* to conduct a similar effort of field work data collection and model analysis to study the reciprocal process of oak maquis development within planted pine forests, and *(iii)* test soil and litter processes of the new emerging ecosystem where pines and oaks coexist. We hypothesize that even

though the two colonization processes create a similar new ecosystem, each of these dynamics is unique due to the different characteristics of the two systems (e.g. high colonization through long-range wind dispersal in pines vs. strong vegetative regeneration and limited seed dispersal in oaks).

6. Budget state report

Purpose	Detailed expenses	Budget	Expenses*	Remaining
Dr. Canham's visit to Israel				
	Flight	1,500 \$	1,324 \$	
	Traveling in Israel:			
	Car rental	250 \$	278 \$	
	Gas	300 \$	164 \$	
	Board and lodging	700 \$	821 \$	
	Subtotal	2,750 \$	2587 \$	163 \$
Efrat's 1st visit to IES (4 weeks)				
	Flight	1,500 \$	1,090 \$	
	Traveling costs	500 \$	152 \$	
	Board and lodging	800 \$	1,100 \$	
	Course tuition and housing	1,050 \$	1,150 \$	
	Subtotal	3,850 \$	3,492 \$	358 \$
Efrat's 2nd visit to IES (24 days)				
	Flight	1,500 \$	800\$	
	Traveling costs	400 \$	175\$	
	Board and lodging	800\$	700\$	
	Subtotal	2,600 \$		1,025\$
Modeling tools:	Laptop computer and software	3,000 \$	2,430 \$	
	Computing tools		400\$	170\$
Overhead		1,300 \$	2,460 \$	- 1,160 \$
TOTAL:		13,600 \$	11,230 \$	

* The budget and most of the expenses in Israel are handed in NIS, and the rate of US dollar to NIS changed drastically during 2008. Expenses in NIS are reported here transformed to a rate of 1 US \$ = 3.5 NIS, as a representative average of 2008. For this reason a final budget according to this budget is not accurate.