Development of village system model for predicting and comparing the success of different interventions

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India launched the National Mission on Medicinal Plants (NMMP) to provide livelihood opportunities for rural entrepreneurs. This study determines effectiveness of the mission in achieving rural sustainability. A case model of Khirvire village, Maharashtra using system dynamics approach is considered to identify the possible externalities which can challenge NMMP effectiveness. It is found that interventions most preferred by the policy and finance are of less preference for the village system. The study concludes that NMMP in its current design will not be sufficient for adequate activities dissemination in the Indian villages.

Keywords: Approach, interventions, medicinal plants, rural development, system dynamics.

IN developing countries, rural–urban development disparity is common that has resulted in poor health status[1], lower wages and higher unemployment risk[2]. A completely urban district like Mumbai has much higher development index than districts like Osmanabad that has 80% of its total population residing in rural areas in Maharashtra, India[3]. Rural development is critical both globally and for developing countries like India because majority of the population[4] as well as the poor live in rural areas[5]. One of the solutions for India is the economic growth of rural areas that has been shown to directly affect rural poverty[6].

Any nation has a pool of interventions that can be implemented in rural areas, but it is critical to select only those that can enable in reducing rural poverty and migration from rural areas. This is because, not all economic growth decisions may show the desirable effects, e.g. increase in real wages may not increase the per capita income if the number of days of wage employment is reduced[2]. In another case, it was shown that promoting rural livelihood diversification alone might not increase the well-being of rural areas. It is important to introduce trade and salary-based livelihood diversification compared to wage- or craft-based livelihood diversification[7].

Any rural area is a complex system containing a large variety of living (like humans, livestock, agriculture, biodiversity) and non-living (policies, food, water, energy) units dynamically interacting with each other. Further, rural areas are different system compared to urban areas as rural households have the unique characteristic of very high livelihood diversification[8]. Therefore, it is important to study the impact of any intervention on the whole rural system for selection of promising interventions. One of the approaches to study the impact is through a dynamic system model that can measure and predict the behaviour of a system when an intervention gets assimilated in the system. The present study aims to understand the village system response to different economic interventions.

In this study, we propose a framework to develop a dynamic model for Indian villages that could help in evaluating various interventions planned and designed for rural areas. The methodology is demonstrated through a case study of implementing the National Mission on Medicinal Plants (NMMP) policy in Khirvire village, Akole Block, Ahmendnagar district, Maharashtra due to ease of data availability for this village.

The study contribution is multifold. First, it provides a methodology to develop a village-level model for testing any rural intervention. Secondly, it provides theoretical contribution by developing a system dynamics approach to predict and understand the impact of a medicinal plant policy in a region. Thirdly, it provides practical implications of the policy on the village under consideration.

India is a biodiversity hotspot that the nation intends to sustainably tap to increase global trade and improve rural livelihood scenario. In this regard, India launched the NMMP in 2008 (ref. 9) and such initiatives can serve as a model for the rest of world if designed and implemented successfully. The mission provides end-to-end linkage support for the sector with subsidy provided for all aspects, from raw material production to processing and marketing. The Mission also provides subsidy for cultivation of certain key medical plants as well as for the setting up of processing units.

Rural areas are the major target points for successful implementation of this Mission. However, no studies are available that modelled the NMMP implementation in rural areas to estimate its success. Further, the policy content[10] and implementation output[11] have been found to be less than desirable. The issues in implementation reiterate the need for studies that could model the rural system and evaluate the impact of NMMP and similar policies in rural areas.

Accordingly, this study proposes a methodology to determine the impact of different policy interventions in rural areas. Using Khirvire village as the case study area and *Phyllanthus amarus* (PA) as a sample herbal plant for implementation, the study creates different policy implementation scenarios. The impact assessment of different implementation scenarios on village economy and livelihood is performed to understand the NMMP policy efficacy on the rural system.

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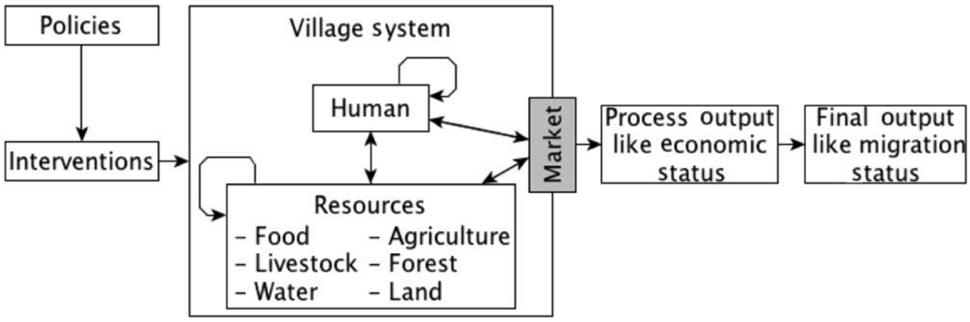

Figure 1. Conceptual framework used in the present study.

Figure 1 shows the conceptual framework. A village is a system that consists of different subsystems. Some of the main subsystems are human population and resources. These subsystems interact with themselves and with each other. Market is considered as the interface point through which a village interacts with its surroundings. These interactions could include economic, social or political based on the study objective. Such village system functioning leads to various process outputs like economic status (say, financially surplus or financially deficit) that affects the final village output like migration rate or status of the people from the village.

The NMMP policy implementation and testing of such a dynamic village system requires conversion of the policy into an intervention scenario, which is introduced in the village system. Multiple intervention scenarios could be created from a single policy. The modelling and measuring impact of these different scenarios could help in local customization of policy and to select the most appropriate policy implementation approach. According to the selected intervention, the change in various indicators of the village system, process output and final output can be measured to determine the intervention impact on the village system. The main objective of this study is to test the policy effectiveness in reducing seasonal migration from villages.

Khirvire village is located at 73°51′E long and 19°38′N lat. Ahmednagar district is the largest district in Maharashtra, occupying 5.66% area of the state. The Akole Block falls in Western Hilly Region and is categorized under Tribal Block category.

Majority of the population in Khirvire village belongs to the scheduled tribes (ST) community named *Hindu Mahadev Koli*. The other communities include backward class, scheduled castes (SC) and general category. The village has eight hamlets and a central habitat. Generally the ST community inhabits hamlets while the other communities mainly inhabit the central habitat. Men are mainly involved in agriculture and local business activities, while women are responsible for performing household activities and providing help with agriculture. Children go to school and help women in their household activities during their spare time. Non-government organizations (NGOs) are involved in creating women self-help groups (SHGs) to empower and help them in better support their families.

Marriages and religious festivals are major social activities that occur in the village, which also have significant impact on its economic activities. The social–economic and resources profile of the village is explained in Supplementary Material Appendix 1.

The NMMP policy focuses on promoting the herbal industry in India. In this regard, herbal industry intervention is tested for Khirvire village. The intent of the policy for villages is to improve their livelihood status by increasing job opportunities in the areas. We first develop a dynamic quantitative village model taking into account the economic, social and demographic characteristics of the village. Next, the theoretical guidelines of NMMP are converted into measurable intervention. This is followed by implementation of the intervention into the village model and analysis of its effect on village development.

A dynamic model for Khirvire village was prepared to capture the complete village system. The data used for building the dynamic model were collected by performing intensive household-level interactions with the villagers, farmers, shopkeepers, staff belonging to different institutions (post office, schools, banks, Primary Health Centre (PHC), dairy collection centres, Anganwadi, ration shop), gram panchayat, active NGOs of the village between May and July 2010. People of all age groups, profession, caste, gender and religion were included to collect the village information and understand the village dynamics.

However, secondary data sources were also used for some of the parameters, namely daily calorie intake required[12] and average calorific value of food[13]. Further, secondary literature was also used to define some of the relationships like population density effect on the human population[12], and effect of amount of fodder consumed by the cattle on the dung produced by them[13].

The village system consists of seven subsystems, namely human population, food, animal population, agriculture, water, forest and land (see Supplementary

Material Appendix 2). The village subsystem does not operate in isolation and interacts with the outside world. In the present case study, the focus is restricted to economic interaction. Accordingly, market subsystem is created that captures economic exchanges between the village system and the outside world.

The output of economic interaction between the village and the outside world will determine the economic status of the village. In this case, a simple formula is used: if the total earnings of the village are less than its total expenditure, then economic status of the village is poor. In such a case, in order to meet the excess expenditure, migration from the village takes place to generate extra funds. However, if the total earnings of the village are greater than or equal to its total expenditure, then the economic status of the village is good. Accordingly, the process output indicator and final village status indicators used for the study are village earnings and migration of people from the village.

Khirvire village has been suffering from distress migration. People have to seasonally or daily migrate to nearby areas to meet their basic household expenditure, since income from agriculture and livestock and subsidies from the Government are not sufficient. Accordingly, the main rural development indicator used for the village is the number of temporary migrants in a year. The permanent migration under distress or due to higher level of education is not considered, as permanent migrants completely move out of the village system and become part of another system. Further, contribution of permanent migrants in the current rural economy like monthly remuneration to the family or relatives is not significant compared to other economic sources for the village.

The indicator is directly dependent on household expenditure and income within the village. The number of temporary migrants in a year is calculated by the number of mandays of migration divided by the number of days in a year. The number of mandays of migration is calculated by the total deficit earning of the village in any given year divided by the product of average daily earnings of the migrant and the number of days in a year. The average daily earnings of the migrant is assumed to be Rs 70. The number of different people moving out of the village will be greater than the calculated of number the temporary migrants because not everyone goes out for the whole year. Some people may migrate only for a few days or months. However, the total number of days migrated by the villagers will be equal to the number of mandays of migration required to meet the economic deficit of the village households.

The NMMP policy focuses on promoting rural economic development by providing financial subsidy for medicinal plants in agriculture and industry. Accordingly, three different scenarios are being created to test different economic interventions. These interventions are various financial models developed for the village (see Jain and Rao)[14]. In brief, the intervention is the setting up of SHG-operated medicinal plant processing industry in the village with processing capacity of 500 kg of raw material (PA) and 160 days of operation (October–March). The scenarios are three different financial models for the industry that are based on the level of processing and source of raw material as shown below:

- Scenario 1: Raw material is collected from nearby forest and industry is low technology.
- Scenario 2: Raw material is collected from nearby forest and industry is high technology.
- Scenario 3: Raw material is supplied from cultivation on land previously used for growing tomato and industry is low technology.

The village system created for Khirvire was simulated to analyse its rural development over the next 25 years in terms of temporary migration from the village. The simulation was performed using the system dynamics approach in Vensim software. It is called the base scenario simulation because no intervention model is added to the village system, which helps in estimating employment and job opportunities for business-as-usual condition in Khirvire village.

The simulation was also run for the village system with each of three intervention models separately. Accordingly, the results for each intervention scenario were obtained separately and compared with each other as well as with the base scenario. The equations and parameters of intervention models were added into the village system to enable it to respond to these interventions (see Supplementary Material Appendix 3). These different interventions may create different impacts on village sustenance over the 25 years period. Scenario 1 is expected to use the minimum policy support among the three scenarios, as it would need policy help only for setting up a low-cost industry. The other two scenarios need more policy support as they have to either set-up high technology industry or perform cultivation activities. Scenarios 1 and 2 are expected to hire more people in the village, as villagers will get additional employment in foraging activities. Additionally, villagers will get employment in the industry. This should reduce migration from the village. Since the collection level is same in both scenarios, reduction in migration should be similar. Scenario 3 may not observe much reduction in migration, as villagers will only get employed in low-cost industry.

Some assumptions have been made with regard to the system and different interventions to make the model simple enough to understand the village system, but also detailed enough to capture the village behavior. First, it is assumed that all the variables and externalities not considered for the system are constant, or do not have significant effect on the system. Secondly, no inflation is assumed for the system. Thirdly, the change in social

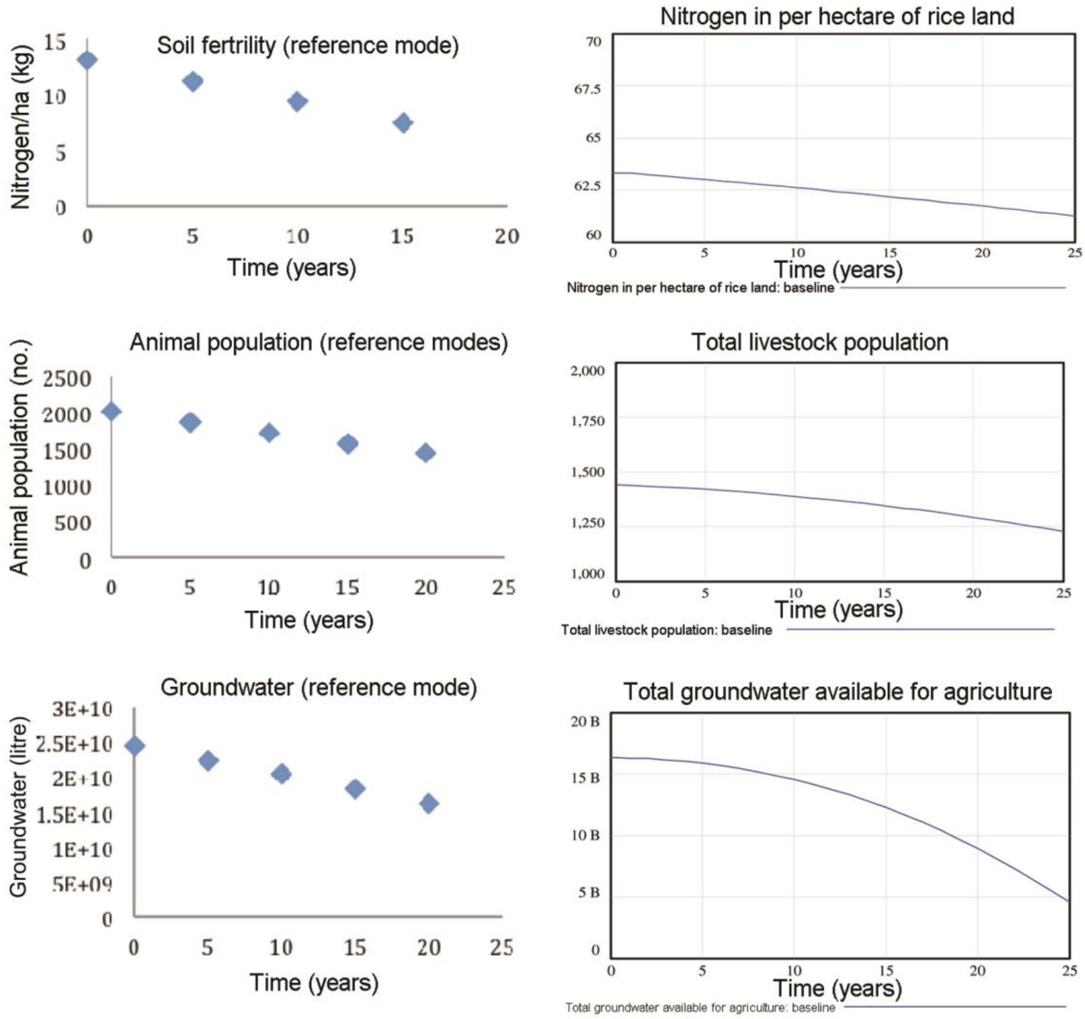

Figure 2. Comparison between reference mode and baseline study for soil fertility, livestock population and groundwater availability. The reference mode graphs represent the trends obtained by plotting data points from the field with time. Baseline study graphs represent the trends obtained from the simulation of no intervention model for the field.

status of people or improvement in literacy rate is assumed to have not much significant effect on the system as they will either permanently migrate from the system or will simply cause a reshuffle in the village hierarchy. Fourthly, the loan amount taken, if any, in the village system, is assumed to be paid at yearly fixed amount till its completion. Finally, it is assumed that no other major intervention will come into the system to significantly alter the results. For scenarios 1 and 2, additional assumption is made that raw material is sufficiently available from the wild. For scenario 3, it is assumed that PA cultivation will be done by substituting tomato crop over 80 ha. Tomato crop is considered rather than rice, because tomato is a cash crop and rice is a food crop. Also, reduction in food production in the village can reduce its food sustainability.

The village model was validated in order to determine if it is able to reflect village field status. The model was validated using few indicators for which historical data were available. These indicators are inherent soil fertility, livestock population and groundwater level. The data collected from the villagers regarding these indicators were relative to the 2010 values, rather than absolute. The pattern obtained for these indicators was compared with the model pattern for them. Ideally, the model should be started with few years behind the current year, so that the pattern of the indicators could be more strongly validated. Since, data were not available for the previous year, the model had to start from 2010 only.

The village modelled in the baseline scenario showed similar decreasing trend for the indicators of soil fertility, livestock population and groundwater (Figure 2). The different intervention scenarios led to a change in the migration and employment status of the village. Employment in the village increased in all cases, but only marginally compared to the requirement (Figure 3). This is because the number of people who can gain employment through industrial set-up is very small, only 4.6 people in a year.

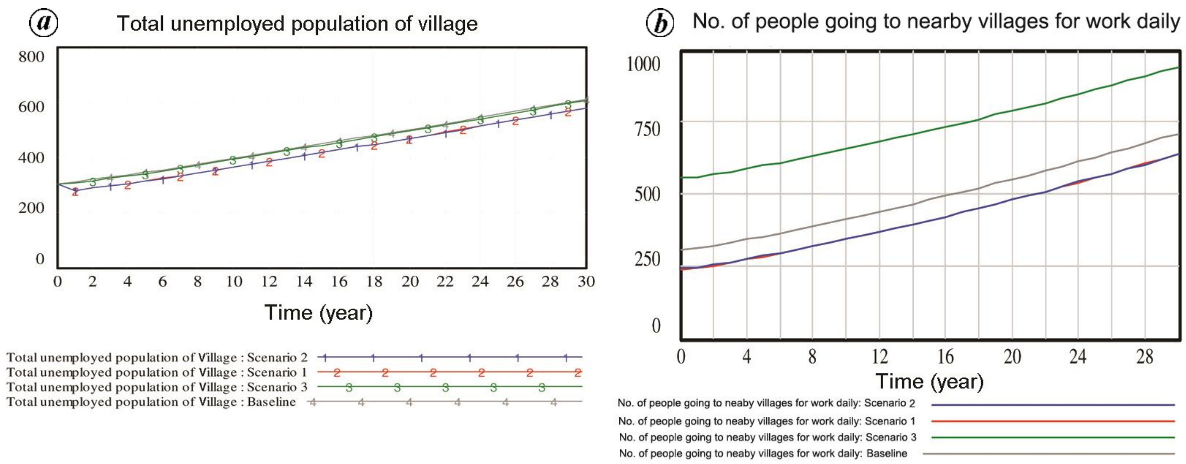

Figure 3. Comparison of scenarios with the baseline for total unemployed population in the village after migration (***a***) and total migration from village (***b***).

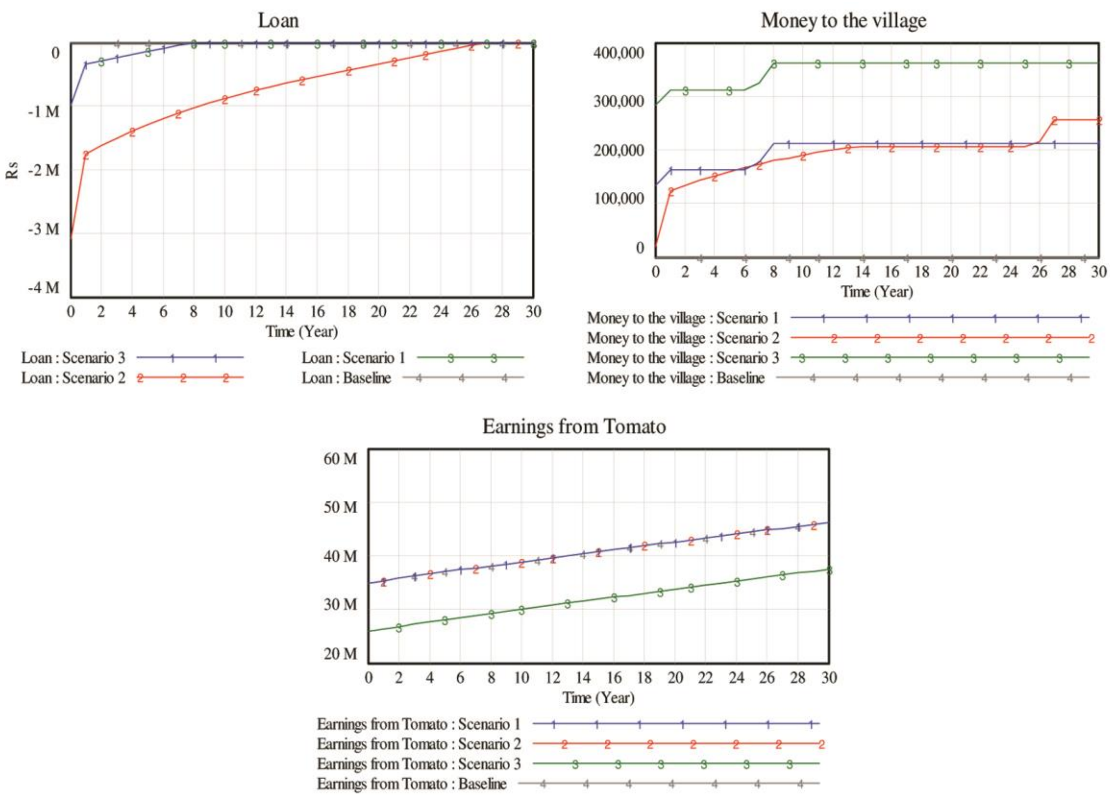

Figure 4. Comparison of different scenarios regarding loan repayment, funds given to the village and earnings from tomato. Baseline scenario: no intervention is made in the village system. Scenario 1: Raw material is supplied from nearby forests and industry is low technology; Scenario 2: Raw material is supplied from nearby forests and industry is high technology; Scenario 3: Raw material is supplied from cultivation on land previously used for growing tomato and industry is low technology.

However, there was better response in scenarios 1 and 2 compared to scenario 3 because seasonal jobs have been created for the collectors.

A small reduction in the migration of people was observed in scenarios 1 and 2 (~15%), but scenario 3 showed an increase in migration (80%) from the baseline (Figure 3). This is because the cultivation of PA will substitute commercial crop in the village, i.e. tomato (Figure 4). This leads to significant reduction in profits and overall reduction in village earnings and thus increase in migration. Further analysis of the model showed that different scenarios had different effects on the total loan repayment and total money earned by the village from industry. Loan repayment was quicker for scenarios 1 and 3 compared to scenario 2. The village earnings from industry were maximum for scenario 3 compared to scenarios 1 and scenario, with the lowest earnings from scenario 1.

Overall, scenario 1 is good for the village as it increases village employment, reduces migration and helps repay loans quickly (attractive for money-lending institutions like banks). Scenario 2 is financially least attractive, while scenario 3, is the most attractive both financially and from a policy perspective as it helps repay loans quickly and uses cultivation as raw material source, but is least attractive for villagers as it will increase their migration.

The development of villages requires different forms of intervention ranging from policy to technology. The intervention success in a village depends on its ability to synchronize with functionality of the existing systems, both socially and economically. This study highlights that more successful interventions for a village are those that can generate overall development and revenue to the system. The system dynamics model of Khirvire village showed the ability of medicinal plants cultivation and industry to reduce village migration thereby strengthening the NMMP objectives. The study provides important insight into the policy objectives and financial plans to help realize the potential unaccounted external forces which can make a highly viable process unviable. Such a system dynamic models can be developed for different villages or regions to understand and determine future development status of the system and accordingly design interventions. These models can be used to evaluate the success of the proposed and implemented interventions in the field. Further, villagers will cultivate medicinal plants only when the income from this is lucrative compared to the commercial crops.

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Received 8 August 2016; revised accepted 17 June 2019

doi: 10.18520/cs/v117/i7/1189-1194

Forest biometric parameter extraction using unmanned aerial vehicle to aid in forest inventory data collection

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Frequent ground surveys and satellite-based information on tree height, canopy gaps and forest dynamics are limited by time, cost and spatial scales. In this study, an attempt has been made to derive forest biometric parameter on tree height by canopy height model and crown area projections using unmanned aerial vehicles (UAV)–RGB image. Sorensen's coefficient has been used as an index to compare between ground inventory and UAV-based species identification. The statistical paired *t*-test showed UAV RGB can be used for maximum tree height and tree crown extraction to aid in ground surveys.

Keywords: Canopy height model, canopy area projection, forest biometry, unmanned aerial vehicles.

ADVANCES in unmanned aerial vehicles (UAV) with improved spatial, spectral and temporal resolution of

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