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Initial Development of Surface Fuel Models for The Netherlands

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Abstract

Estimating the spread of wildland fire is growing concern in the Netherlands, where fire events at the wildland urban interface is a growing concern with a changing climate. A multi-year project was initiated in 2012 to obtain field-based fuel measurements to be used to estimate wildland fire spread for surface fire. The overall objective was to develop either custom fuel models or utilize existing Northern American fuel models to fuel conditions in some of the hazardous vegetation in the Netherlands. Over a four-year period, 96 plots were established, a wide variety of fuel parameters measured, and ANOVA (p ≤ 0.1) and Duncan's MRT used to place these into 56 different vegetation categories. Following multiple permutations in Behave plus, the 56 communities were consolidated into 28 different fuel models. It was then attempted to use these fuel models as input variables in a Dutch-developed wildland fire spread model. Some fuel models produced similar fire spread, and since they were within relatively similar communities, were combined, resulting in 21 working fuel models. The results of this project will provide land managers, fire brigades and landowners more accurate wildland fire spread estimations, improving safety of the public in this densely populated country. The results of this project will contribute to more accurate and detailed calculations of the NBVM (Dutch wildfire spread model). The NBVM will provide necessary information, to be able to reduce the risk on uncontrollable wildfires, via wildfire prevention measurements and during an incident, to support decision making.

Keywords: Wildland fire; Fire behavior; Spread model

Introduction

While the Netherlands is known for their efforts to prevent flooding, it is not known as a country where wildfires occur. Wildfires do happen every year in the Netherlands, but on a much smaller scale (e.g., a wildfire at the National Park Hoge Value in 2014 was 350 hectares) than in South Europe, Australia, Canada and United States; these wildfires still have major local impact and had the attention of the politicians, the public and the press. In the Netherlands, there is a great interrelationship between nature/wildland, infrastructure, houses, recreation, commonly known as wildland urban interface. So even a relative small wildfire can cause great risk, and have an impact on both the environment and the public.

For many years a standard rule has been used in the Netherlands during a wildfire. However, this generic estimate was rarely accurate, nor did it take into account the various fuel conditions found around the country. The Institute Fysieke Veiligheid (Institute for Safety, IFV) started the development of a more accurate Dutch wildfire spread model by command of the Ministry of Safety and Justice in 2009.

A literature review was initiated to find a computer model to estimate the spread (speed and direction) of a wildfire that can be adapted to the Dutch situation [1]. The possibilities, usability and the wishes from the fire departments were obtained through a variety of interviews to find the right model structure to adapt for use in the Netherlands. The literature review and the interviews combined identified the North American wildfire model FARSITE the best choice. The mathematical part of this program was used to construct the Dutch Wildfire Spread model (NBVM).

The initial decision was made to make the NBVM calculations with four very basic fuel models. Each fuel model contains information about the fuel bed characteristics, and is therefore different per vegetation type. A basic map of the Netherlands, called TOP10NL was used for the NBVM; this map contains five legend units that could be linked with an existing fuel model used in the United States. Broadleaf forest was linked with TL6 [2], mixed forest with TU2, coniferous forest to TU3 and heather to an adapted grassland model [3]. The initial choice of these fuel models was based on the description of the vegetation [4]. This adaptation was necessary since there were no specific fuel models for heather fields. Validation during wildfires and prescribed burning was used for the adaptation of this grassland model [3]. These fuel models contained information about the biomass, amount of burnable material in a specific vegetation type, and used for mapping high risk areas [5].

To improve the linkage between fuel models and vegetation types in the Netherlands, field fuel research was initiated in 2012. Using input from wildland managers, we began with a basic fuel model classification of four common nature types in the Netherlands: dry heather, dune area, peat and undergrowth forest.

The overall goal of this study was the development of custom fuel models or to link of vegetation types found in the Netherlands with existing Northern American fuel models. The specific objectives were to identify: 1) which American fuel models be used for the Dutch vegetation types, and, if so, which; and 2) which vegetation types require custom fuel models.

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Adding fuel models, based on the data of the fuel research, to the NBVM, further develops and allows for more accurate simulations of the potential spread of a wildfire.

Material and Methods

Fuel research

Field fuel research was conducted between 2012 and 2015 by IFV, in cooperation with Stephen F. Austin State University (SFA) in Texas and the University of Applied Sciences van Hall Larenstein (VHL) Velp, the Netherlands. Each year, fieldwork was conducted supervised on-site by IFV, and data analysis was conducted at SFA. The vegetation classification of SNL (a Dutch uniform subsidy system) was followed. This vegetation index is used nationwide in the Netherlands by all major wildland/nature organizations and is therefore the most suitable index (www.bij12.nl). Within this index priorities were identified for the vegetation types that form a potential risk on the occurrence and the spread of a wildfire [6]. For each vegetation type, a goal was a minimum six different plots to capture differences in biomass, age and composition of the vegetation to obtain a range of conditions.

The first research season took place on dry sandy sites supporting heather fields, and the undergrowth under scots pine, Douglas fir and beech, as well as two exploratory plots performed in grasslands. Measurements in 2013 were in various dune types: open dune, dune grassland, dune heather, dune valley and dune shrub. The first four were investigated on Texel Island (Northern part of the Netherlands), and sites near Harlem and Amsterdam for dune shrub.

Peat areas were measured in 2014 in Northumberland (North England) for peat grasslands, heather fields, shrub and forests since Northumberland has a large area of peat that access was easily obtained. Northumberland is comparable to sites in the Netherlands as they are in the same climate zone. In the Netherlands peat areas are smaller and are considered vulnerable to any disturbance, which made research in the Netherlands nearly impossible. In addition to the research in the UK a small scale comparable research was performed in Aamsveen (eastern part of the Netherlands).

In 2015 measurements were conducted in the undergrowth of different forest types. Plots that were utilized in 2012 and 2014 were utilized, as were new plots in areas such as peat forests. Plots were also performed in dune forest, conifer, broadleaf and mixed forests. The fieldwork took place in Aamsveen (peat forest), National Park duinen van Texel (dune forest), National Park Loonse and Drunense duinen and New Forest in England (conifer, broadleaf and mixed).

Fieldwork

The field protocol initially developed by Ottmar [7] was modified for this research (Figure 1). The following measurements were taken: 50 litter and duff measurements, 31 transects (15.4 m) for herbaceous cover, 12 circular plots (3 m radius) crown densities and shrubs and trees, and 25 plots (1 m²) for the herbaceous species. Each plot was given a site/plot code, and pictures of each site taken. A fish-eye lens on a camera was also utilized to characterize forest canopy conditions. GPS coordinates, slope, aspect and dominant vegetation were recorded. In addition, five samples are taken of the litter and duff layer to determine the bulk density at S1, L2S7, S13, L9, S19 and S25. Samples were weighed, dried in an oven at 90°C for 48 hours and weighed again. Crown density is measured at all the L’ points in four cardinal directions with a densitometer, and a mean canopy cover calculated.

The transects were initiated at ‘S’ and ‘L’ points. The direction of each transect was randomly determined, but had to fall within the outside lines as shown in Figure 1. Along each transect, percent cover by species, litter, mineral soil, downed woody material, etc. was recorded. For the downed woody material, the size class was also recorded [8,9].

The three-meter radius plots were located at the ‘L’ points. All trees and shrubs within the plot were recorded by species, the DBH (diameter breast height) and the diameter of the base of the tree measured with a D-tape the total height, height of the first dead branch and the height of the live crown were measured with a clinometer for each tree within the plot. The size of the crown was estimated, widest dimension and then perpendicular. For shrubs the total height, ground diameter and crown width was also measured, and seedlings recorded by species.

Each 1 m² plots were located at the ‘S’ points, and the herbaceous and grass species recorded, per species the cover percentage estimated, and mean height of the herbaceous and grass species calculated.

Statistical analysis

All data was entered into Excel and an Analysis of Variance (ANOVA) using SAS 9.0 was performed on fuel parameters (downed woody material by size, total herbaceous, including cover and height, litter, humus depth, over story, shrub) for biomass on an Mg ha⁻¹ basis to identify significant differences (p ≤ 0.1) in fuel loadings per site and within vegetation types.

Total fuel load was used as the initial parameter to identify significant differences across and within major types, and then the measured parameters that drive fire behavior within that type (e.g., SAV for grasslands, downed woody material in Coniferous forests) were used to further identify if significant differences occurred within the various types. Duncan’s Multiple Range Test was then performed to identify which sites were statistically different. Similar sites were then grouped together within each community type.

These results were then compared to existing fuel models from the United States, and if consistent in fuel loads, were given an existing model code (e.g., TL3). When the conditions did not fit an existing model, a custom model was then developed. Depending whether in the
concerned vegetation type herbaceous species are present or not a fuel model was determined to be dynamic (herbaceous layer present) or static (no herbaceous species).

The range of fuel conditions for each site type and fuel model were then run 100 times through Behave Plus, a computer program which can be used to predict potential fire behavior [10]. Slight changes in fuel parameters and/or weather conditions were made for each run, and potential fire behavior outputs (rate of spread (km hr$^{-1}$), mean or maximum intensity (kW m$^{-2}$), and mean flame height (m) determined, a fire behavior class label given, and for custom models, a new model code given.

Discussion

Developing accurate estimates of wildfire spread in new environments where wildfire fire has had limited attention was challenging. Rather than working in historically fire-prone conditions as found in North America, Australia and the Mediterranean region, the Netherlands we working in environments where fire has had little historic presence, and where fire's role as an ecological agent may be minimal. It is because of this that it is the government agencies responsible for emergency preparedness and safety such a IFV that are taking the lead on this issue, rather than the natural resource managers as found in the United States.

The reduction of the number of types of fuel conditions from the fieldwork without losing valuable data was not surprising, since we didn't have any idea what fuel conditions would result in significant difference in potential wildland fire spread. When you consider that the initial fuel models developed in the United States for Behave in the 1970's reduced potential conditions down to 11 or 13 [2,11], we found that our reduction to 21 is actually less conservative, and may avoid future needs to expand the number of models as now are acknowledged [4], in addition to the custom model option in Behaveplus.

What was especially challenging was when all fuel parameters fit into an existing fuel model, but then would not work in the spreadmodel. Even using dryer-than-normal weather conditions for the Netherlands did not result in an accurate fire spread, or no fire spread at all. The highly fragmented landscape found in the Netherlands compared that found in the western United States and Canada may have contributed to some models not producing fire spread characteristics that were observed at wildfires. It is possible that landscape scale might be a variable that should be incorporated into the Dutch spread model as they continue to improve its accuracy.

The results of this study did add 21 fuel models to the NBVM contributing to more accurate calculations. This is of great value in a small-scale country like the Netherlands, with a great interrelationship of land use, infrastructure and population density. By adding fuel models to the NBVM, a more specific calculation can be made which can contribute to scenarios to indicate high risk areas. This is useful information for wildfire prevention measures. In addition, a more detailed calculation of the NBVM contributes also to the support of the fire brigade by making decisions during a wildfire.

To be able to add the 21 fuel models to the NBVM a more detailed map was necessary. Therefore, a project was started to create detailed and up-to-date vegetation maps with satellite data. The potential usage of the firespread models is high. Any user of the NBVM can via the TOP10NLM and/or coordinates, identify the location of the start of a wildfire. It is also possible to make a calculation based on an existing fire front. Besides the location, the user also needs to enter meteorological data of seven days previous of the wildfire: temperature (minimum and maximum), relative humidity (minimum and maximum) and precipitation. For the day of the wildfire the wind speed, in meters per second, and the wind direction is entered. Via meteorological data and fuel models, the NBVM produces a calculation of the spread of a wildfire for the next six hours. In addition, potential firelines can be drawn in the model to be able to see the effect, and multiple fires can be calculated at the same time.

The results of this research and fuel models needs to be further validated for the Netherlands. This can also be done in countries with a same climate zone, like the UK and Germany. Wildfires and prescribed burns can be used to validate all of the selected fuel models. For the vegetation types that need custom fuel models, for example heather, additional research on the SAV ratio’s (surface area volume) is necessary, and was initiated in 2016 and 2017, as well as research in calculating canopy fuel to estimate crown fire spread and spot fire probabilities. In addition, satellite data shall be used to create ‘fuel maps’, consisting of different vegetation types to which the fuel models are linked. The goal of the fuel map is more details but also more up-to-date (once a year an update of the vegetation and twice a year an update of the biomass).

Results

Between 2012 and 2015, 93 different plots were established and utilized for this study. These plots were then given a Site Label to provide a short description of the site, resulting in 56 different labeled communities (Table 1, Initial Site Label). Using Analysis of Variance and Duncan’s MRT, distinct statistical differences (p ≤ 0.1) were found between all of the community types and between some of the plots within each type. Fuel data was then compared to existing US fuel models to provide an initial starting point for estimating potential wildfire spread utilizing BehavePlus, reducing the 96 plots to 28 initial fuel models (Table 1, Initial Fuel Model), each statistically different from the others.

Each of these initial fuel models for each site were then utilized in BehavePlus, slightly changing the appropriate input variables for that model 100 times and results compiled. The results were then compared to Behaveplus outputs for US models, and if they fell within one Standard Deviation of the means provided for the US model, they were left in that model. If the resulting parameters exceeded 1 Standard Deviation, they were evaluated to see if they fell within another existing US model, or should be placed in a custom model. If the later, they were then again run 100 times in a custom model scenario, and the results recorded. The resulting outputs were then given 23 revised site labels to simplify descriptions of the sites based on similar estimated fire behaviors (e.g., the 6 different Beech communities from 2012 were given the same label (Broadleaf Forest no understory) since they all modelled the same regardless of our initial observations (Table 1, Revised Site Label).

The next step was to see whether all these models could be used in the Dutch wildfire spreadmodel. A number of proposed models were found not to work within the parameters within the spreadmodel; as a result, a selection was made by data out of fieldwork. This data was combined and used to create new fuel models (Table 1, Fire Spread Model Code). This process was based on the vegetation classification of SNL with a translation to a logic classification for the NBVM (biomass), since biomass has a great influence on the fire behavior. Also, this selection was made in comparison with the data of several wildfires since biomass has a great influence on the fire behavior. Also, this selection was made in comparison with the data of several wildfires, and was initiated in 2016 and 2017, as well as research in calculating canopy fuel to estimate crown fire spread and spot fire probabilities. In addition, satellite data shall be used to create ‘fuel maps’, consisting of different vegetation types to which the fuel models are linked. The goal of the fuel map is more details but also more up-to-date (once a year an update of the vegetation and twice a year an update of the biomass).
### Initial Site Label | Initial Fuel Model (or Farsite fuel model) | Revised Site Label | Fire Spread Model Code (Dutch)
--- | --- | --- | ---
**2012**
- Beech
  - TL9
  - Broadleaf Forest no understory
  - L1
- Upland Beech
  - TL9
  - Broadleaf Forest no understory
  - L1
- Beech-Mixed Hardwood
  - TL9
  - Broadleaf Forest no understory
  - L1
- Beech closed Canopy
  - TL9
  - Broadleaf Forest no understory
  - L1
- Dense Beech 1
  - TL9
  - Broadleaf Forest no understory
  - L1
- Dense Beech 2
  - TL9
  - Broadleaf Forest no understory
  - L1
- Thick Grass
  - GR9
  - Grassland
  - GR3
- Moderate Grass
  - GR8
  - Grassland
  - GR2
- Thinned DF (2plots)
  - TL3
  - Coniferous Forest-shrub undergrowth
  - N4
- Regenerating DF
  - TU5
  - Coniferous Forest-shrub undergrowth
  - N3
- Thin DF
  - TU5
  - Coniferous Forest-shrub undergrowth
  - N3
- Dense DF
  - TL3
  - Coniferous Forest-no understory
  - N4
- Mature DF
  - TL3
  - Coniferous Forest-shrub undergrowth
  - N4
- Stripped O Horizon
  - H1
  - Heather (dry sandy ground)
  - H1
- Grazed
  - H1
  - Heather (dry sandy ground)
  - H1
- Heather 2
  - H2
  - Heather (dry sandy ground)
  - H1
- Heather-Grass
  - H3
  - Heather (dry sandy ground)
  - H2
- Heather-Grass
  - H3
  - Heather (dry sandy ground)
  - H2
- Heather-Scattered Pine
  - H3
  - Heather (dry sandy ground)
  - H2
- Scots Pine 1
  - SP1
  - Conifer forest
  - N2
- Thick Scots Pine
  - SP2
  - Conifer forest
  - N2
- Scots Pine-Shrubs
  - SP3
  - Conifer forest
  - N3
- Scots Pine-Birch
  - SP3
  - Conifer forest
  - N3
- Dense Scots Pine-Shrubs
  - SP3
  - Conifer forest
  - N3
**2013**
- Dune Grassland 1
  - GR7
  - Dune grassland
  - OD2
- Dune Grassland 2
  - GR3
  - Dune grassland
  - OD1
- Grazed Dune Grassland 1
  - GR5
  - Dune grassland
  - DG1
- Mod. Thick Dune Heather
  - H4
  - Dune heather
  - H3
- Dune Heath 1
  - H5
  - Dune heather
  - H3
- Dune Heath 2
  - H5
  - Dune heather
  - H3
- Thick Dune Heather
  - H5
  - Dune heather
  - H3
- Grazed Dune Heath
  - H4
  - Dune heather
  - H3
- Mowed Dune Heath
  - H1
  - Dune heather
  - H1
- Dune Valley Grassland-Shrub
  - GS4
  - Dune valley
  - ST1
- Dune Valley Shrub
  - SH6
  - Dune valley
  - ST2
- Thick Dune Valley Shrub
  - SH9
  - Dune valley
  - ST2
- Mowed Dune Valley
  - GS3
  - Dune valley
  - ST1
- Sparse Load Open Dune Grass
  - ODG1
  - Grassland-open dune
  - OD1
- Very Low Load Open Dune Grass
  - ODG2
  - Grassland-open dune
  - DG1
- Low Load Open Dune Grass
  - ODG3
  - Grassland-open dune
  - DG1
- Low Load Open Dune Grass
  - ODG3
  - Grassland-open dune
  - OD1
- High Load Open Dune Grass
  - ODG4
  - Grassland-open dune
  - OD2
- Dune Grassland-Shrub
  - GS 4
  - Dune grassland-shrub
  - ST1
- Dune Grassland-Shrub
  - GS 4
  - Dune grassland-shrub
  - ST1
- Dune Grassland-Shrub
  - GS 3
  - Dune grassland-shrub
  - ST1
- Dune Shrub-Grass 1
  - SH8
  - Dune grassland-shrub
  - ST2
- Dune Shrub-Grass 2
  - SH9
  - Dune grassland-shrub
  - ST2
- Open Dune Shrub-Grass
  - GS4
  - Dune grassland-shrub
  - ST1
- Coastal Dune Shrub
  - ODGS1
  - Dune shrub
  - ST2
**2014**
- Peatland Bog (2 plots)
  - GR3
  - Peatland bog
  - GR4
- Peatland Bog (6 plots)
  - GR6/8
  - Peatland bog
  - GR5
- Peatland Heather (3 plots)
  - SH6
  - Peat heather
  - H4
- Peatland Heather (4 plots)
  - SH8
  - Peat heather
  - H4
**2015**
- Dune Forest (Pinus nigra) (2 plots)
  - TL1
  - Dune forest
  - N4
- Dune Forest (Pinus nigra)
  - TL3
  - Dune forest
  - N4
<table>
<thead>
<tr>
<th>Revised Site Label</th>
<th>Revised Model Code</th>
<th>Fire Spread Model Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Forest no understory</td>
<td>TL9</td>
<td>L1</td>
<td>Broadleaf forest, no undergrowth</td>
</tr>
<tr>
<td>Grassland</td>
<td>GR8</td>
<td>GR9</td>
<td>Grass higher than 1 meter, mostly Molinia caerulea, dry sandy area</td>
</tr>
<tr>
<td>grassland (dry) 2</td>
<td>GR9</td>
<td>GR8</td>
<td>Grass lower than 1 meter, mostly Molinia caerulea, dry sand area</td>
</tr>
<tr>
<td>Conifer Forest 2/Conifer Forest 4</td>
<td>TU3</td>
<td>N2</td>
<td>Dense conifer forest, no undergrowth</td>
</tr>
<tr>
<td>Conifer Forest-no understory</td>
<td>TL3</td>
<td>N4</td>
<td>Dense conifer forest, no undergrowth</td>
</tr>
<tr>
<td>Heather 1</td>
<td>H1</td>
<td>H1</td>
<td>Young heather smaller than 30 cm</td>
</tr>
<tr>
<td>Heather 2</td>
<td>H2</td>
<td>H1</td>
<td>Young heather smaller than 30 cm</td>
</tr>
<tr>
<td>Heather 3</td>
<td>H3</td>
<td>H2</td>
<td>Heather mixed with grass</td>
</tr>
<tr>
<td>Conifer Forest 2</td>
<td>SP1</td>
<td>N2</td>
<td>Open conifer forest with low shrub</td>
</tr>
<tr>
<td>Conifer Forest 3</td>
<td>SP3</td>
<td>N3</td>
<td>Open conifer forest with dense shrub</td>
</tr>
<tr>
<td>Open Dune 2</td>
<td>GR7</td>
<td>OD2</td>
<td>Typical white dune vegetation, with mainly Ammophila arenaria</td>
</tr>
<tr>
<td>Open Dune 1</td>
<td>GR3</td>
<td>OD1</td>
<td>Open vegetation, typical white dune habitat with species like Ammophila arenaria and Elytrigia juncea</td>
</tr>
<tr>
<td>Dune Grassland 1</td>
<td>DG1?</td>
<td>DG1</td>
<td>Dune grassland, grey dune habitat</td>
</tr>
<tr>
<td>Heather 3</td>
<td>H4?</td>
<td>H3</td>
<td>Old heather, higher than 30 cm</td>
</tr>
<tr>
<td>Dune Heather</td>
<td>H1</td>
<td>H1</td>
<td>Young heather smaller than 30 cm</td>
</tr>
<tr>
<td>Shrub 2</td>
<td>SH 6</td>
<td>ST2</td>
<td>(Dune) shrub</td>
</tr>
<tr>
<td>Shrub 1</td>
<td>GS3/4</td>
<td>ST1</td>
<td>Low (dune) shrub</td>
</tr>
<tr>
<td>Grassland-open dune</td>
<td>ODG1/3</td>
<td>OD1</td>
<td>Open vegetation, typical white dune habitat with species like Ammophila arenaria and Elytrigia juncea</td>
</tr>
<tr>
<td>Dune Grassland 1</td>
<td>DG1?</td>
<td>DG1</td>
<td>Dune grassland, grey dune habitat</td>
</tr>
<tr>
<td>Open Dune 1/Dune grassland 1</td>
<td>DG1?</td>
<td>OD1/DG1</td>
<td>Open vegetation, typical white dune habitat with species like Ammophila arenaria and Elytrigia juncea</td>
</tr>
<tr>
<td>Grassland-open dune</td>
<td>GR7/ODG4</td>
<td>OD2</td>
<td>Typical white dune vegetation, with mainly Ammophila arenaria</td>
</tr>
<tr>
<td>Shrub 1</td>
<td>GS 3</td>
<td>ST1</td>
<td>Low (dune) shrub</td>
</tr>
<tr>
<td>Peatland Bog</td>
<td>GR 3</td>
<td>GR4</td>
<td>Grassland (wet)</td>
</tr>
<tr>
<td>Peatland Bog</td>
<td>GR 6/8</td>
<td>GR5</td>
<td>Grassland (wet)</td>
</tr>
<tr>
<td>Peat Heather</td>
<td>SH6/8</td>
<td>H4</td>
<td>Peat heather, wet areas</td>
</tr>
<tr>
<td>Peat Shrub</td>
<td>ST1</td>
<td>Low (dune) shrub</td>
<td>Low (dune) shrub</td>
</tr>
<tr>
<td>Peat Forest</td>
<td>x</td>
<td>V1</td>
<td>Peat forest</td>
</tr>
</tbody>
</table>

Table 1: Site labels and fuel models for plots used to quantify fuel loads for the development of the Dutch Wildland Spreadmodel.
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References