

Supplementary information (SI)

Table S1a: Overview of the variable subgroups of all model approaches considered in our review (part 1: climate, site, stand, bark beetle biology); binary classification: 0 = not included, 1 = partially or fully included (the level of detail and degree of inclusion of the variable subgroups varies between approaches; in some cases, input variables were only considered very roughly in models)

Model group	Authors, year	Climate	Site		Stand			Bark beetle biology (and population)			
		Climate	Terrain / Latitude	Soil	Tree	Stand / Cohorts	Growth dynamics	Population size	Development and phenology	Dispersal	Fitness
Phenology	Lange et al. 2006	1	0	0	0	0	0	0	1	0	0
Phenology	Baier et al. 2007	1	1	0	0	0	0	0	1	0	0
Phenology	Jönsson et al. 2007	1	0	0	0	0	0	0	1	0	0
Phenology	Jönsson et al. 2011	1	1	0	0	0	0	0	1	0	0
Phenology	Ogris 2017	1	1	0	0	0	0	0	1	0	0
Phenology	Jakoby et al. 2019	1	0	0	0	0	0	1	1	0	0
Phenology	Ogris et al. 2019	1	1	0	0	0	0	0	1	0	0
Phenology	Jentschke 2025	1	1	0	0	0	0	0	1	0	0
Dispersal	Fahse & Heurich 2011	1	0	0	1	1	0	1	0	1	1
Dispersal	Kausrud et al. 2011	0	0	0	1	1	0	1	1	1	1
Dispersal	Kautz et al. 2014	0	0	0	1	0	0	1	0	1	1
Dispersal	Økland et al. 2016	0	0	0	1	0	0	1	0	1	0
Dispersal	Doležal et al. 2016	0	0	0	0	0	0	1	1	1	0
Dispersal	Louis et al. 2016	0	0	0	1	1	0	1	0	1	0
Dispersal	Potterf & Bone 2017	0	0	0	1	1	0	1	1	1	1
Dispersal	Honkaniemi et al. 2018	0	0	0	1	0	1	1	1	1	1
Driver	Netherer & Nopp-Mayr 2005	1	1	1	0	1	0	0	1	0	0
Driver	Lausch et al. 2011	1	1	1	0	1	0	0	0	0	0
Driver	Overbeck & Schmidt 2012	1	1	1	0	1	0	0	0	0	0
Driver	Stadelmann et al. 2013b	1	0	0	0	1	0	0	1	0	0
Driver	Hlásny & Turčáni 2013	0	1	1	0	1	0	0	0	0	0
Driver	Kärvemo et al. 2014b	0	1	1	0	1	0	0	0	0	0
Driver	Pasztor et al. 2014	1	1	1	0	1	0	0	1	0	0
Driver	Seidl et al. 2016	1	1	1	0	1	0	0	0	0	0
Driver	Radl et al. 2017	1	0	1	0	1	0	0	1	0	0
Driver	Marini et al. 2017	1	1	0	0	0	0	0	0	0	0
Driver	Mezei et al. 2017	1	0	0	0	1	0	0	1	0	0
Driver	Blomqvist et al. 2018	0	1	1	1	1	0	0	0	0	0
Driver	de Groot & Ogris 2019	1	1	1	1	1	0	0	0	0	0
Driver	Rammer & Seidl 2019a	1	1	1	0	1	0	0	0	0	0
Driver	Netherer et al. 2019	1	1	1	0	1	0	0	1	0	0
Driver	Stereńczak et al. 2020	0	1	0	1	1	0	0	0	0	0
Driver	Koreň et al. 2021	1	0	0	0	1	0	0	0	0	0
Driver	de Groot & Ogris 2022	1	1	1	0	1	0	0	0	0	0
Driver	Müller et al. 2022	0	1	1	1	1	0	0	0	0	0
Driver	Jaime et al. 2022	1	0	0	1	1	0	0	0	0	0
Driver	Thari et al. 2022	1	1	1	0	1	0	0	0	0	0
Driver	Kärvemo et al. 2023	1	0	1	0	1	0	0	0	0	0
Driver	Nardi et al. 2023	1	1	1	0	1	0	0	0	0	0
Driver	Nordkvist et al. 2023	1	0	1	0	1	0	0	1	0	0
Driver	Hallas et al. 2024b	1	0	0	0	0	0	0	0	0	0
Driver	Washaya et al. 2024	0	0	0	0	1	0	0	0	0	0
Driver	Kozhoridze et al. 2024	1	1	0	0	1	0	0	0	0	0
Driver	Vodde et al. 2025	0	1	1	1	1	0	0	0	0	0
Driver	Candotti & Tomelleri 2025	0	1	0	0	1	0	0	0	0	0
Ecosystem	Seidl et al. 2007	1	1	1	0	1	1	0	1	0	0
Ecosystem	Seidl et al. 2009	1	1	1	0	1	1	0	1	0	0
Ecosystem	Seidl et al. 2012	1	1	1	1	1	1	0	0	0	0
Ecosystem	Jönsson et al. 2012	1	1	1	0	1	1	1	1	0	1
Ecosystem	Temperli et al. 2013a	1	1	1	0	1	1	1	1	0	0
Ecosystem	Seidl & Rammer 2017	1	1	1	1	1	1	1	1	1	1
Ecosystem	Rammer & Seidl 2019a	1	1	1	0	1	1	0	1	1	0
Ecosystem	Temperli et al. 2020	1	1	1	1	1	1	0	1	0	0
Ecosystem	Marie et al. 2024	1	1	1	0	1	1	0	1	0	1
Ecosystem	Das et al. 2025	1	1	1	1	1	1	1	1	1	1
Combination	Kissiyar et al. 2005	1	1	0	0	1	0	0	0	0	0
Combination	Thiele et al. 2017	1	1	1	0	1	1	0	1	0	0
Combination	Matthews et al. 2018	1	1	1	1	1	0	0	1	0	0
Combination	Đuračiová et al. 2020	1	1	0	0	1	0	0	0	0	0
Combination	Pietzsch et al. 2021	1	1	1	1	1	0	1	1	1	1
Combination	Pietzsch et al. 2023	1	1	1	1	1	0	1	1	1	1
Combination	Thrippleton et al. 2023	1	1	1	1	1	1	0	0	0	0
Combination	Pirtskhalava-Karpova et al. 2024	1	1	1	0	1	0	0	1	0	0
Combination	Hallas et al. 2024a	1	1	1	1	1	0	0	1	0	0
Combination	Kautz et al. 2025	1	1	0	1	1	0	0	1	0	0

Table S1b: Overview of the variable subgroups of all model approaches considered in our review (part 2: bark beetle damage, other disturbances); binary classification: 0 = not included, 1 = partially or fully included (the level of detail and degree of inclusion of the variable subgroups varies between approaches; in some cases, input variables were only considered very roughly in models)

Model group	Authors, year	Bark beetle damage					Other disturbances (and inciting factors)				
		Infestation symptoms	Infestations	Salvage and sanitation	Damaged volume	Distance	Storm	Snow	Drought	Other disturbances	Mortality
Phenology	Lange et al. 2006	0	0	0	0	0	0	0	0	0	0
Phenology	Baier et al. 2007	0	0	0	0	0	0	0	0	0	0
Phenology	Jönsson et al. 2007	0	0	0	0	0	0	0	0	0	0
Phenology	Jönsson et al. 2011	0	0	0	0	0	0	0	0	0	0
Phenology	Ogris 2017	0	0	0	0	0	0	0	0	0	0
Phenology	Jakoby et al. 2019	0	0	0	0	0	0	0	0	0	0
Phenology	Ogris et al. 2019	0	0	0	0	0	0	0	0	0	0
Phenology	Jentschke 2025	0	0	0	0	0	0	0	0	0	0
Dispersal	Fahse & Heurich 2011	0	1	0	0	1	0	0	0	0	0
Dispersal	Kausrud et al. 2011	0	1	0	0	1	0	0	0	0	0
Dispersal	Kautz et al. 2014	0	1	0	0	1	0	0	0	0	0
Dispersal	Økland et al. 2016	0	1	0	0	1	1	0	0	0	0
Dispersal	Doležal et al. 2016	0	0	0	0	0	0	0	0	0	0
Dispersal	Louis et al. 2016	0	1	0	0	1	0	0	0	0	0
Dispersal	Potterf & Bone 2017	0	1	0	0	1	1	0	0	0	0
Dispersal	Honkaniemi et al. 2018	0	1	0	0	1	1	0	0	1	0
Driver	Netherer & Nopp-Mayr 2005	0	0	0	0	0	1	1	0	0	0
Driver	Lausch et al. 2011	0	1	0	0	1	1	0	0	0	1
Driver	Overbeck & Schmidt 2012	0	0	1	0	0	0	0	0	0	0
Driver	Stadelmann et al. 2013b	0	1	1	0	0	0	0	0	0	0
Driver	Hlásny & Turčáni 2013	0	0	1	0	1	0	0	0	0	0
Driver	Kärvemo et al. 2014b	0	1	1	0	1	0	0	0	0	0
Driver	Pasztor et al. 2014	0	1	1	0	0	1	1	0	0	0
Driver	Seidl et al. 2016	0	1	0	0	1	0	0	1	0	0
Driver	Radl et al. 2017	0	1	0	0	0	1	1	0	0	1
Driver	Marini et al. 2017	0	0	0	1	0	1	0	0	0	0
Driver	Mezei et al. 2017	0	0	0	1	0	1	0	0	0	0
Driver	Blomqvist et al. 2018	1	1	0	0	0	0	0	0	0	0
Driver	de Groot & Ogris 2019	0	0	1	0	0	1	1	0	0	0
Driver	Rammer & Seidl 2019a	0	1	0	1	1	0	0	0	0	0
Driver	Netherer et al. 2019	0	0	1	0	0	1	1	1	0	0
Driver	Stereńczak et al. 2020	0	1	0	0	1	0	0	0	0	0
Driver	Koreň et al. 2021	0	1	0	0	1	0	0	0	0	1
Driver	de Groot & Ogris 2022	0	0	1	0	0	1	1	0	0	0
Driver	Müller et al. 2022	0	0	1	0	1	0	0	0	0	0
Driver	Jaime et al. 2022	0	1	0	0	0	0	0	1	0	1
Driver	Thari et al. 2022	0	0	0	0	0	0	0	1	0	0
Driver	Kärvemo et al. 2023	0	1	1	0	0	1	0	1	0	1
Driver	Nardi et al. 2023	0	1	0	0	1	0	0	1	0	0
Driver	Nordkvist et al. 2023	0	0	0	0	0	1	0	0	0	0
Driver	Hallas et al. 2024b	0	0	0	1	0	1	1	0	0	0
Driver	Washaya et al. 2024	0	1	0	0	1	0	0	0	0	1
Driver	Kozhoridze et al. 2024	0	0	0	0	0	0	0	0	0	0
Driver	Vodde et al. 2025	0	1	0	0	1	1	0	0	0	0
Driver	Candotti & Tomelleri 2025	0	1	0	0	1	0	0	1	0	0
Ecosystem	Seidl et al. 2007	0	0	0	1	0	0	0	1	0	1
Ecosystem	Seidl et al. 2009	0	0	0	1	0	0	0	0	0	1
Ecosystem	Seidl et al. 2012	0	0	1	0	0	0	0	0	0	1
Ecosystem	Jönsson et al. 2012	0	1	1	0	0	1	0	0	0	1
Ecosystem	Temperli et al. 2013a	0	1	0	1	1	1	0	1	1	1
Ecosystem	Seidl & Rammer 2017	0	1	1	1	1	1	0	0	0	1
Ecosystem	Rammer & Seidl 2019a	0	1	0	1	1	1	0	0	0	1
Ecosystem	Temperli et al. 2020	0	0	1	1	0	1	0	0	1	1
Ecosystem	Marie et al. 2024	0	1	0	1	0	1	0	0	0	1
Ecosystem	Das et al. 2025	0	1	1	1	1	1	0	1	0	1
Combination	Kissiyar et al. 2005	0	1	0	0	1	1	0	0	0	0
Combination	Thiele et al. 2017	0	0	0	0	0	1	0	1	1	1
Combination	Matthews et al. 2018	0	0	0	0	0	0	0	0	0	0
Combination	Đuračiová et al. 2020	0	1	0	0	1	1	0	0	0	1
Combination	Pietzsch et al. 2021	0	1	1	0	1	1	0	0	0	0
Combination	Pietzsch et al. 2023	0	1	1	0	1	1	0	0	0	0
Combination	Thrippleton et al. 2023	0	0	1	0	0	1	0	0	0	0
Combination	Pirtskhalava-Karpova et al. 2024	0	1	0	0	0	0	0	1	0	0
Combination	Hallas et al. 2024a	0	1	0	1	1	1	1	1	0	1
Combination	Kautz et al. 2025	0	1	0	0	0	0	0	1	0	0

Table S1c: Overview of the variable subgroups of all model approaches considered in our review (part 3: management); binary classification: 0 = not included, 1 = partially or fully included (the level of detail and degree of inclusion of the variable subgroups varies between approaches; in some cases, input variables were only considered very roughly in models)

Model group	Authors, year	Forest management		
		Management regimes	Accessibility	Timber processing capacities
Phenology	Lange et al. 2006	0	0	0
Phenology	Baier et al. 2007	0	0	0
Phenology	Jönsson et al. 2007	0	0	0
Phenology	Jönsson et al. 2011	0	0	0
Phenology	Ogris 2017	0	0	0
Phenology	Jakoby et al. 2019	0	0	0
Phenology	Ogris et al. 2019	0	0	0
Phenology	Jentschke 2025	0	0	0
Dispersal	Fahse & Heurich 2011	0	0	0
Dispersal	Kausrud et al. 2011	0	0	0
Dispersal	Kautz et al. 2014	0	0	0
Dispersal	Økland et al. 2016	0	0	0
Dispersal	Doležal et al. 2016	0	0	0
Dispersal	Louis et al. 2016	0	0	0
Dispersal	Potterf & Bone 2017	0	0	0
Dispersal	Honkaniemi et al. 2018	0	0	0
Driver	Netherer & Nopp-Mayr 2005	0	0	0
Driver	Lausch et al. 2011	0	0	0
Driver	Overbeck & Schmidt 2012	0	0	0
Driver	Stadelmann et al. 2013b	0	0	0
Driver	Hlásny & Turčáni 2013	0	0	0
Driver	Kärvemo et al. 2014b	0	0	0
Driver	Pasztor et al. 2014	0	0	0
Driver	Seidl et al. 2016	0	0	0
Driver	Radl et al. 2017	0	0	0
Driver	Marini et al. 2017	0	0	0
Driver	Mezei et al. 2017	0	0	0
Driver	Blomqvist et al. 2018	0	0	0
Driver	de Groot & Ogris 2019	0	0	0
Driver	Rammer & Seidl 2019a	0	0	0
Driver	Netherer et al. 2019	0	0	0
Driver	Stereńczak et al. 2020	0	0	0
Driver	Koreň et al. 2021	0	0	0
Driver	de Groot & Ogris 2022	0	0	0
Driver	Müller et al. 2022	0	0	0
Driver	Jaime et al. 2022	0	0	0
Driver	Thari et al. 2022	0	0	0
Driver	Kärvemo et al. 2023	0	0	0
Driver	Nardi et al. 2023	0	0	0
Driver	Nordkvist et al. 2023	1	0	0
Driver	Hallas et al. 2024b	0	0	0
Driver	Washaya et al. 2024	0	0	0
Driver	Kozhoridze et al. 2024	0	0	0
Driver	Vodde et al. 2025	0	0	0
Driver	Candotti & Tomelleri 2025	0	0	0
Ecosystem	Seidl et al. 2007	1	0	0
Ecosystem	Seidl et al. 2009	1	0	0
Ecosystem	Seidl et al. 2012	1	0	0
Ecosystem	Jönsson et al. 2012	1	0	0
Ecosystem	Temperli et al. 2013a	1	0	0
Ecosystem	Seidl & Rammer 2017	1	0	0
Ecosystem	Rammer & Seidl 2019a	1	0	0
Ecosystem	Temperli et al. 2020	1	0	0
Ecosystem	Marie et al. 2024	1	0	0
Ecosystem	Das et al. 2025	1	0	0
Combination	Kissiyar et al. 2005	0	0	0
Combination	Thiele et al. 2017	1	0	0
Combination	Matthews et al. 2018	0	0	0
Combination	Đuračiová et al. 2020	0	0	0
Combination	Pietzsch et al. 2021	0	0	0
Combination	Pietzsch et al. 2023	0	0	0
Combination	Thrippleton et al. 2023	1	0	0
Combination	Pirtskhalava-Karpova et al. 2024	0	0	0
Combination	Hallas et al. 2024a	0	0	0
Combination	Kautz et al. 2025	0	0	0