Repowering Köthen II

Prediction by using the

Space Use Collision Risk Model

(RKR model)

Expert report ordered by Test Client

provided by

PredictBird

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Project coordination and report

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Client

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Contractor

PredictBird GmbH is a joint venture of TB Raab GmbH, TNL Energie GmbH, BioConsult SH GmbH & Co. KG, and Bionum GmbH established for the purpose of the simplified, standardised, and verified application of the Space Use Collision Risk Model (RKR model).

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1. Project description - Repowering Köthen II

The Repowering project is located within the municipality of Petersberg in the federal state of Sachsen-Anhalt. It is planned to consist of 2 wind turbines (WTGs) (cf. Table 1). In the repowering project Köthen II, 3 existing WTGs are to be replaced by 2 modern wind turbines on behalf of Test Client. The current planning includes 2 turbines of the type V172 with a hub height of 175 m.

The planned project is located outside the designated Natura 2000 areas. The project area is defined by the locations of the planned wind turbines. The analysis primarily focuses on a 1,200 m buffer around each turbine considered (cf. Figure 1). Within the 1,200 m evaluation area (central evaluation area) of the project area, there are 3 breeding places of red kite.

The project area is subdivided according to the evaluation zones for red kite specified in Section 45b Annex 1 of the German BNatSchG, into the close range (500 m), the central evaluation area (ranging from 500 m to 1,200 m) and the extended area of evaluation (from 1,200 m to 3,500 m).

Table 1: Presentation of the parameters of the 2 planned (Pi/Planned) wind turbines and the 3 existing turbines to be replaced (Di/Deconstructed) within the Köthen II repowering project

ID	Hub height [m]	Rotor radius [m]	Free rotor space [m]	Rotations [1/min]	Average rotor blade depth [m]	Maximum rotor blade depth [m]
P1	175.0	86.0	89.00	7.50	2.81	4.35
P2	175.0	86.0	89.00	7.50	2.81	4.35
D1	105.0	45.0	60.00	9.72	2.21	3.51
D2	105.0	45.0	60.00	9.72	2.21	3.51
D3	105.0	45.0	60.00	9.72	2.21	3.51

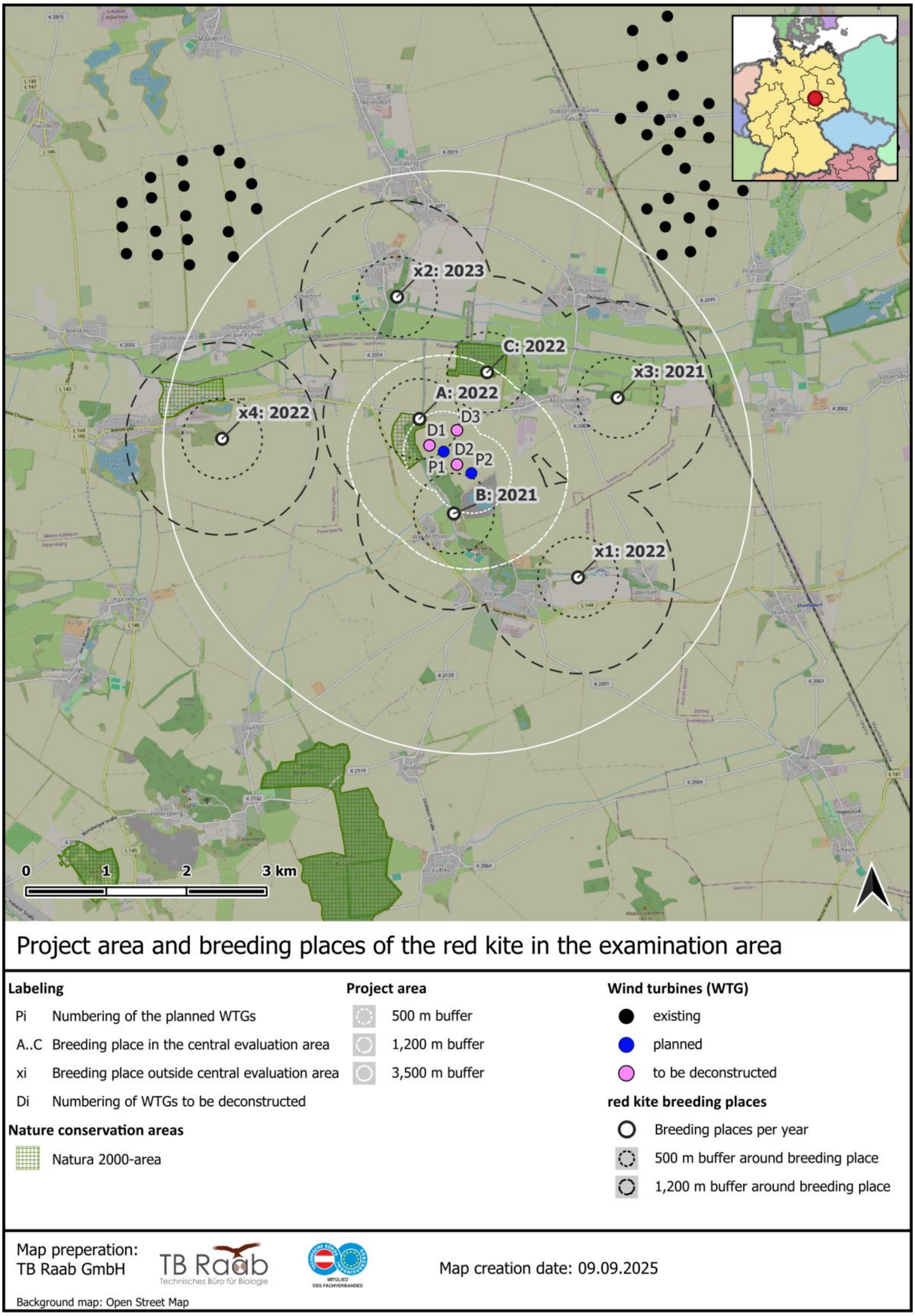

Figure 1: Known breeding places (white points) of the red kite from the years 2021, 2022 and 2023 in the vicinity of the project area. The project area is shown with the planned WTGs (blue).

2. Introduction and Methodical overview

According to Section 74 (6) first sentence of the German BNatSchG, "…the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), together with the Federal Ministry for Economic Affairs and Climate Action (BMWK), has been tasked with examining the introduction of a probabilistic method by 30 June 2023 and, following consultation with stakeholders, presenting a report or a draft law or ordinance" (German Bundestag printed matter 20/9830 of 15 December 2023). The summary states: "In the present review report, the Federal Government recommends introducing the probabilistic method for calculating the collision probability of breeding birds at onshore wind turbines (WTGs) in 2024, initially for the red kite, and then gradually for additional breeding bird species." This explicitly refers to the method applied here. Its preliminary version was referred to as the "Hybrid Model" in the "Pilotstudie Probabilistik" and, in the finalised version of the "Fortsetzungsstudie Probabilistik," as the "Space Use Collision Risk Model" (RKR model) (Mercker et al., 2023 & 2024).

The RKR model, as a probabilistic calculation method, enables the integration of technological advances in remote sensing (e.g., the EU Copernicus programme) in combination with objective movement data from telemetry (birds equipped with GPS trackers). This approach allows for the standardised, transparent, and precise generation of scientifically sound results to quantify space use and collision risk of breeding birds at wind turbines (WTGs), while maintaining low uncertainties and reproducible outcomes (based on a calculation procedure defined by a standardised methodology).

The model empirically incorporates, in line with the current state of research, those factors relevant to collision risk, such as three-dimensional space use depending on habitat, species-specific avoidance behaviour at wind turbines, current breeding place information derived from expert field surveys, as well as the average rotational speed and dimensions of the turbines.

Further information and technical details on the calculation rule used in the RKR model can be found in Mercker et al. (2023 & 2024) and are available on the websites of the KNE (at https://www.naturschutz-energiewende.de/fachwissen/probabilistik-in-der-signifikanz-bewertung/) and PredictBird (www.predictbird.de).

As the developers of the RKR Model, we emphasise that the calculation methodology applied here corresponds to the model that was extensively validated and verified within the pilot and follow-up studies. The thorough validation included, among other aspects (but not limited to):

- the qualitative and quantitative comparison of model predictions with empirically collected external data and studies, which recorded either collision victims or time spent within the WTG risk area. In all four cases, the model predictions corresponded closely to the actual numbers (Mercker et al., 2023, 2024);
- the validation and verification of all model assumptions, modelling steps, and results by more than 30 representatives of federal and state ministries in Germany as well as experts from the fields of nature conservation, wind energy, species protection law, and biostatistics within the UAG-2 (Sub-working group Probabilistics, one of three sub-working groups mandated by the German Conference of Environment Ministers [UMK] to develop legally robust assessment standards for the approval of wind turbines) and two additional project-accompanying working groups. It is important to highlight that, in

all essential aspects regarding model assumptions and the plausibility of the results, there was consensus among all participants;

- a systematic comparison of the predicted space use by the RKR Model with hundreds of real distribution patterns, demonstrating that the predictive accuracy has improved many times over compared to previous methods;
- statistical evidence showing that the estimated (and used for predictions) habitat suitability is independent of large-scale region, sex of the birds, and inclusion or exclusion of individual GPS datasets, making the model predictions robust and transferable.

These studies culminated in the development of a calculation procedure for precisely this RKR Model, which also forms the basis of the methodology applied in this study.

For its parametrisation, Mercker et al. (2023 & 2024) analysed the behaviour of more than 170 breeding red kites based on several million regularised telemetry points distributed across Germany and Austria. Adaptations of the RKR Model to other species (such as white stork and white-tailed eagle) are currently being developed in further calculation guidelines.

Regarding local, species-specific habitat suitability, the above-mentioned tracking data were digitally intersected with more than 4,000 habitat parameters prepared by TB Raab and Bionum and derived variables, and analysed using the “integrated step selection method” (iSSM) (Avgar et al., 2016; Mercker et al., 2021), which is currently an established and statistically validated method for analysing habitat suitability based on tracking data (Mercker et al., 2021) and is increasingly applied as a predictive tool (Aiello et al., 2023; Fieberg et al., 2021; Potts & Börger, 2023).

The coordinates of the breeding places are provided in advance by the commissioning parties. To calculate the collision risk for a specific combination of WTG and breeding place, location-specific, habitat-dependent input parameters are used. Additionally, WTG characteristics such as location, hub height, rotor diameter, and rotor blade depth are considered. The RKR model retrieves the corresponding habitat information from free data sources (Copernicus Corine Land Cover, Copernicus High-Resolution Layer, OpenStreetMap) and derives a prediction of habitat suitability and flight height distribution. Furthermore, the WTG-specific parameters are used to calculate the configuration-specific collision risk in combination with the predicted space use.

In the present case, the model predicts space use based on the number of hours (flying or perching) during the breeding season (March to September) within a 10 km radius around the breeding place. Based on this, the collision risk per individual and breeding season is determined for the specific local combination of WTG, breeding place, and habitat. It is implicitly assumed that the bird survives throughout the entire period; other causes or probabilities of mortality are not considered.

The calculation method consists of two separate model functions:

In a first step, a prediction of the three-dimensional, project-specific space use of of the red kite is made using probabilistic methods, based on the current habitat (factors such as forests, pastures, settlements, etc.). These predictions rely on statistical analysis of a large volume of empirical movement data collected via telemetry and analysed in the “Fortsetzungsstudie Probabilistik” (Mercker et al., 2023 & 2024), considering species-specific habitat suitability, habitat-dependent flight height distribution, diurnal flight activity, and the distance to the breeding place. In predicting space use densities based on habitat suitability, wind turbines are initially disregarded; avoidance behaviour at different scales is incorporated separately (see below).

In a second step, the predicted space use densities for each breeding place are combined with WTG-specific data of the planned wind farm to estimate the mean number of seconds spent within the risk area (i.e., the airspace swept by the rotor blades) per individual and season. Here, the empirically determined meso-avoidance (cf. Mercker et al., 2023 & 2024) is considered. These seconds in the risk area are converted (based, among other factors, on empirical flight data) into the number of rotor passes, and the collision risk per pass (and derived per individual and season) is then determined using the established mechanistic collision risk model by Band (Band, 2012, 2000; Band et al., 2007). In this step, the dynamic and static WTG and bird parameters play a role. The flight speed, the body dimensions of the bird and the empirically determined micro-avoidance are taken into account for each species. This results in a total avoidance of around 0.98 (98 %) for the red kite (Mercker et al., 2024).

The WTG parameters relevant for the model and used in the following are presented in Table 1. While an increasing rotor radius and/or rotor blade depth leads to a higher collision risk, a greater hub height (with the same rotor radius, and thus a higher minimum blade passage) generally results in the risk area being used less intensively by red kites and consequently reduces the collision risk. The number of turbine revolutions per minute is approximated according to the “Fortsetzungsstudie Probabilistik” (Mercker et al., 2024) with a value for the wind speed of 5 m/s at hub height for the breeding season (and taking into account the rotor diameter of the turbine).

The mean and maximum rotor blade depth, together with the mean body size of the bird, are the parameters used to determine the depth of the risk area and are therefore also incorporated into the RKR Model. The mean rotor blade depth is defined as the average of the maximum rotor blade depth and the blade depth measured at 90% of the rotor radius.

The RKR model is used to calculate the individual risk of a breeding bird per WTG breeding place combination. If the cumulative collision risk of an individual with a wind farm is calculated using the individual risks for specific WTGs, this is done by using the following formula:

$$K = 1 - \prod_{i=1}^{n} (1 - k_i)$$

- K: Risk of a specific breeding individual colliding with the evaluated wind farm in the respective breeding season.
- k_i: Risk of a specific breeding individual colliding with the wind turbine (i) in the respective breeding season.

-n: Number of WTGs in the evaluated wind farm.

This formula makes it possible to correctly represent individual risks calculated.

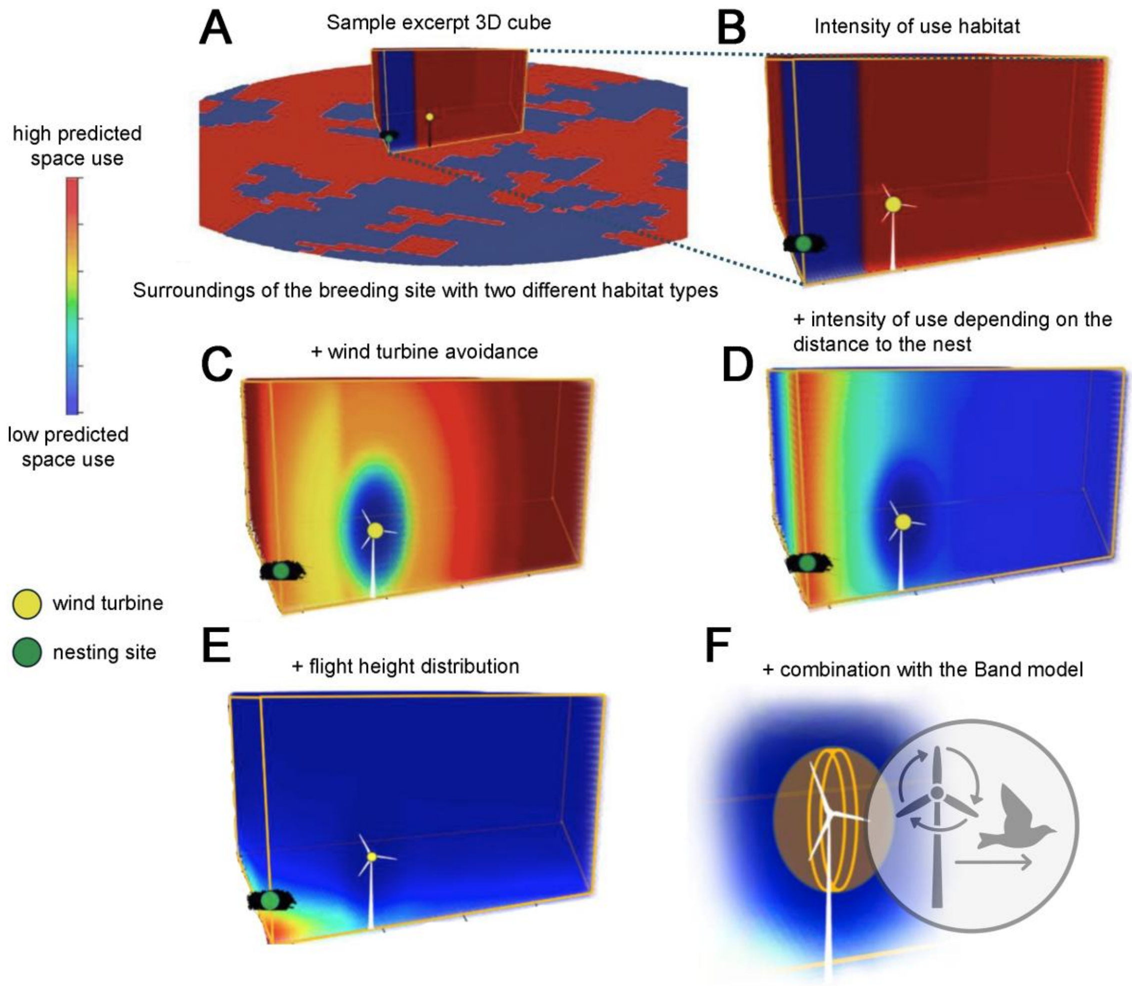

Figure 2: Illustration of the RKR model methodology. In (A) to (E), the predicted (and empirically based) 3D space use is established step by step, namely (A)-(B) the continuation of 2D space use (depending on habitat/land use) into 3-dimensional space (exemplarily limited to a cuboid); (C) the addition of the WTG avoidance behaviour; (D) the space use as a function of the distance to the breeding place; (E) and the habitat-dependent flight height distribution. (F) Combination of the predicted space use with temporal parameters and the collision risk model to calculate the final collision risk. Warm colours indicate (relatively speaking) higher space use, cold colours indicate low space use (scaled between near 0 and 1 for each cuboid). Graphic from the „Fortsetzungsstudie Probabilistik" (Mercker et al., 2024).

3. Integration of the Habitat Situation

Through a differentiated, comprehensive, and specific preparation of a wide range of habitat parameters, approximately 4,000 potentially relevant parameters were available on a nation-wide scale for Germany, Austria, and Slovakia within the scope of the “Fortsetzungsstudie Probabilistik” (Mercker et al., 2024). It was found that regarding the red kite, in particular the high-resolution layers (HRL) “small woody features” (hedgerows and shrub groups), “imperviousness” (sealed surfaces), “grassland” (grassland and meadows), and “tree cover density” (trees) from Copernicus have a high explanatory value. In contrast, distinguishing between deciduous, coniferous, and mixed forests is not significant and is therefore not implemented. Arable land from Corine as well as major roads (source: Open Street Map) and settlement areas (source: CorineDE) are also of considerable importance. In Figure 3, these habitats are illustrated. In Figure 4, the barrier effect of forest (see also Annex 1) for determining the preferred orientation of the nearest red kite breeding place is shown. The barrier effect often influences the local extent of home range use to an even greater degree.

Accordingly, the RKR model uses (in addition to variables that depend on the distance to the breeding place) the following habitat parameters:

1. Hedgerows or shrub groups within a 100 m radius (swfDens0100)
2. Density of forest in the 20 x 20 m grid cell (treeDens0000)
3. Density of arable land within a 500 m radius in the grid cell (allCropsDens0500)
4. Distance to the nearest forest area (treeDist)
5. Distance to the nearest grassland or meadow area (grassCopDist)
6. Sealed surfaces / imperviousness within a 100 m radius (imperDens0100)
7. Distance to the nearest arable land (allCropsDist)
8. Density of secondary roads (regional connecting roads, e.g., state roads) within a 100 m radius (secondaryDens0100)
9. Density of grassland or meadows in the 200 x 200 m grid cell (grassCopDens0200)
10. Distance to the nearest hedgerow or shrub group (swfDist)
11. Barrier effect of forest (costDist_tree)
12. Density of arable land within a 1,000 m radius (allCropsDens1000)
13. Density of settlement areas within a 100 m radius (settlementDens0100)
14. Density of major roads (“primary, secondary, motorway & trunk”) within a 100 m radius (roadDens0100)
15. Distance to the nearest forest area larger than 3 ha (treeDist03Ha)
16. Sealed surfaces / imperviousness within a 2,500 m radius (imperDens2500)

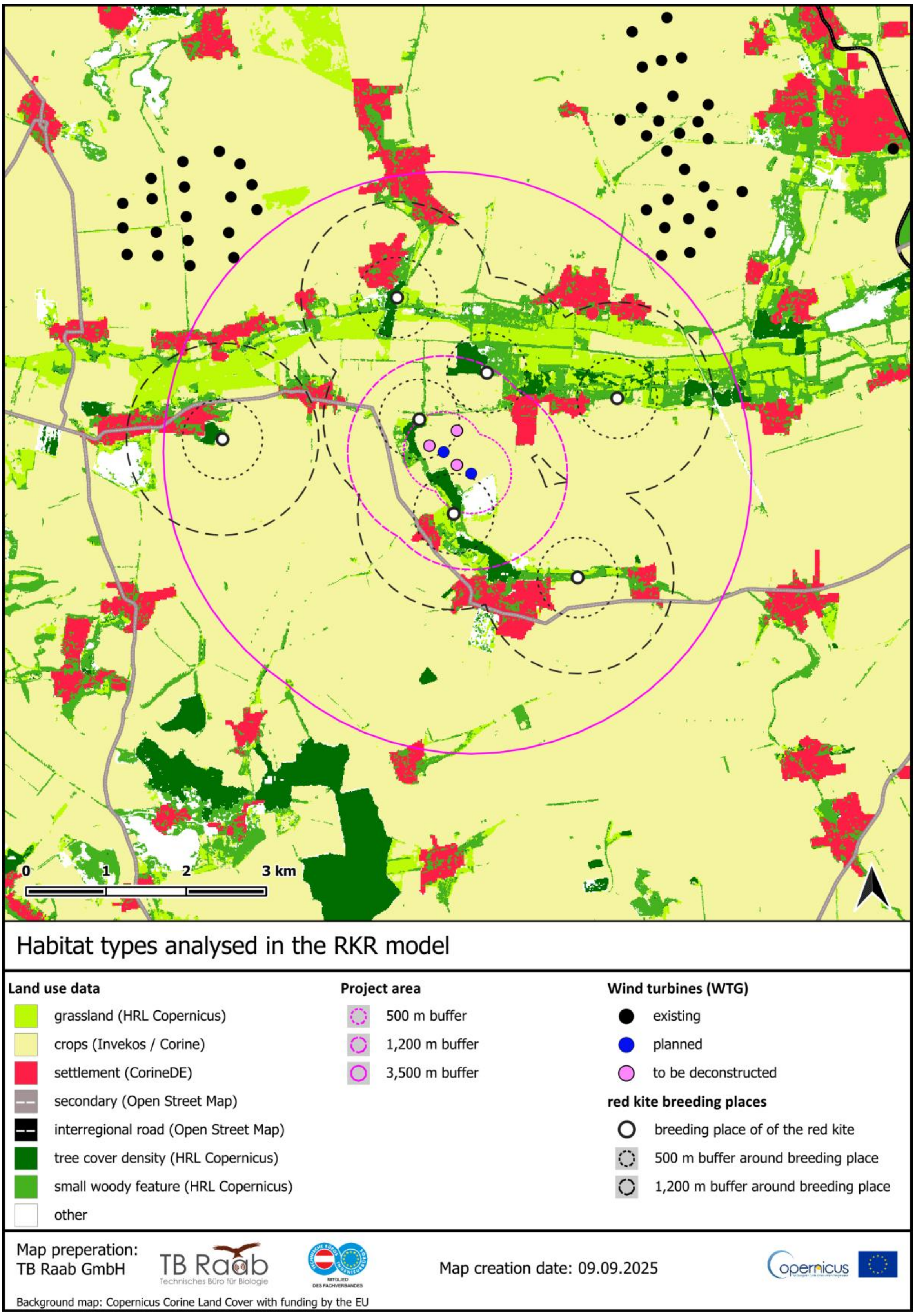

Figure 3: Habitat types used for the "RKR model prediction" according to the "Fortsetzungsstudie Probabilistik" (Mercker et al., 2024).

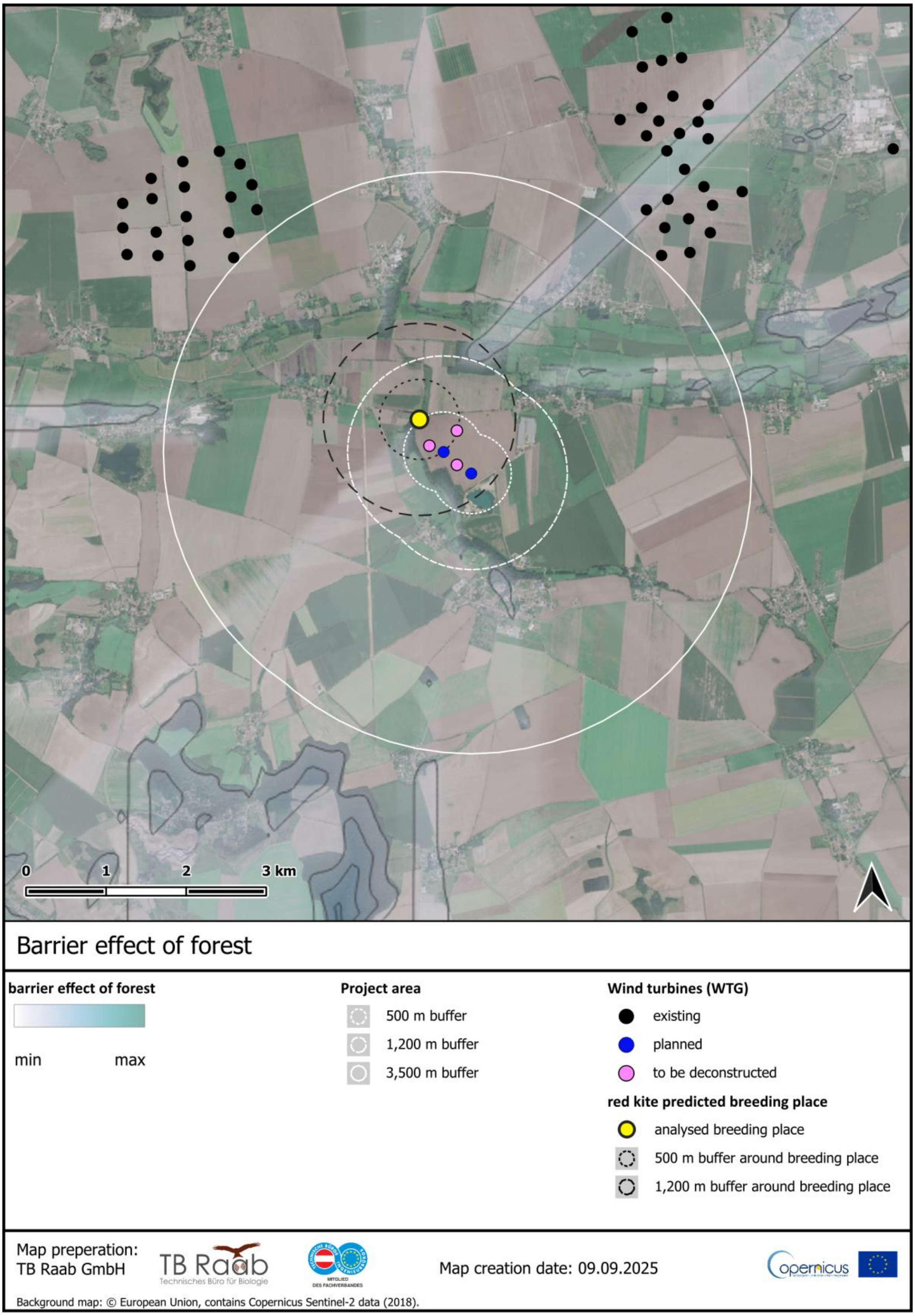

Figure 4: Barrier effect of forest and its effect on space use of the red kite is shown; in this case calculated from a real breeding place considered as an example (shaded areas). White and grey areas indicate a weak barrier effect, green/blue areas a strong one.

4. Habitat Potential Analysis (HPA)

With the RKR model, it is possible to predict and illustrate both habitat effects on red kite breeding birds without the additional dependence on the distance to a certain red kite breeding place (referred to as "Habitat Potential" – cf. Figure 5) and the space use of a specific breeding pair (cf. Figures in Chapter 4.1). The latter results from the combined influence of habitat and distance to the breeding place and is referred to as project-specific "space use" (in reference to a space use analysis, RNA). Both the habitat potential and the space use describe the three-dimensional area in which a certain proportion of flying time is predicted to occur.

Relative Habitat Potential for Breeding birds

For predicting the habitat potential within the project area (including buffer zones) for flying red kites, the methods described in Mercker et al. (2024) as part of the "Fortsetzungsstudie Probabilistik" are applied. In particular, the regression results presented there for the habitat iSSM are used to predict, separately for each habitat class, the relative attraction for the project area.

Since the aim is to assess the relative intensity of use within the project area rather than absolute values, the result of the combined use intensity can be rescaled. For improved interpretability, the result is therefore divided by the mean of the calculated (combined) use intensity within the project area (including buffer zones), so that the final mean value of the relative use intensity equals 1. Accordingly, values <1 indicate relative avoidance (within the project area), whereas values >1 indicate local attraction (within the project area).

In Figure 5, the (breeding place-independent) habitat potential within the project area for breeding birds is presented.

Prediction regarding the breeding places within the central evaluation area

Within the 1,200 m buffer around the wind energy planning area, 3 breeding places of red kite have been identified, which therefore overlap the WTG sites with their species-specific core evaluation zones. For these breeding places, the predicted space use is presented below in two separate maps each.

The focus of the first map for each breeding place is on illustrating the predicted space use differentiated by areas of varying flight activity (0 to 90%), whereas the second figure exclusively depicts the areas of high flight intensity (0 to 60%) and emphasises the underlying habitats.

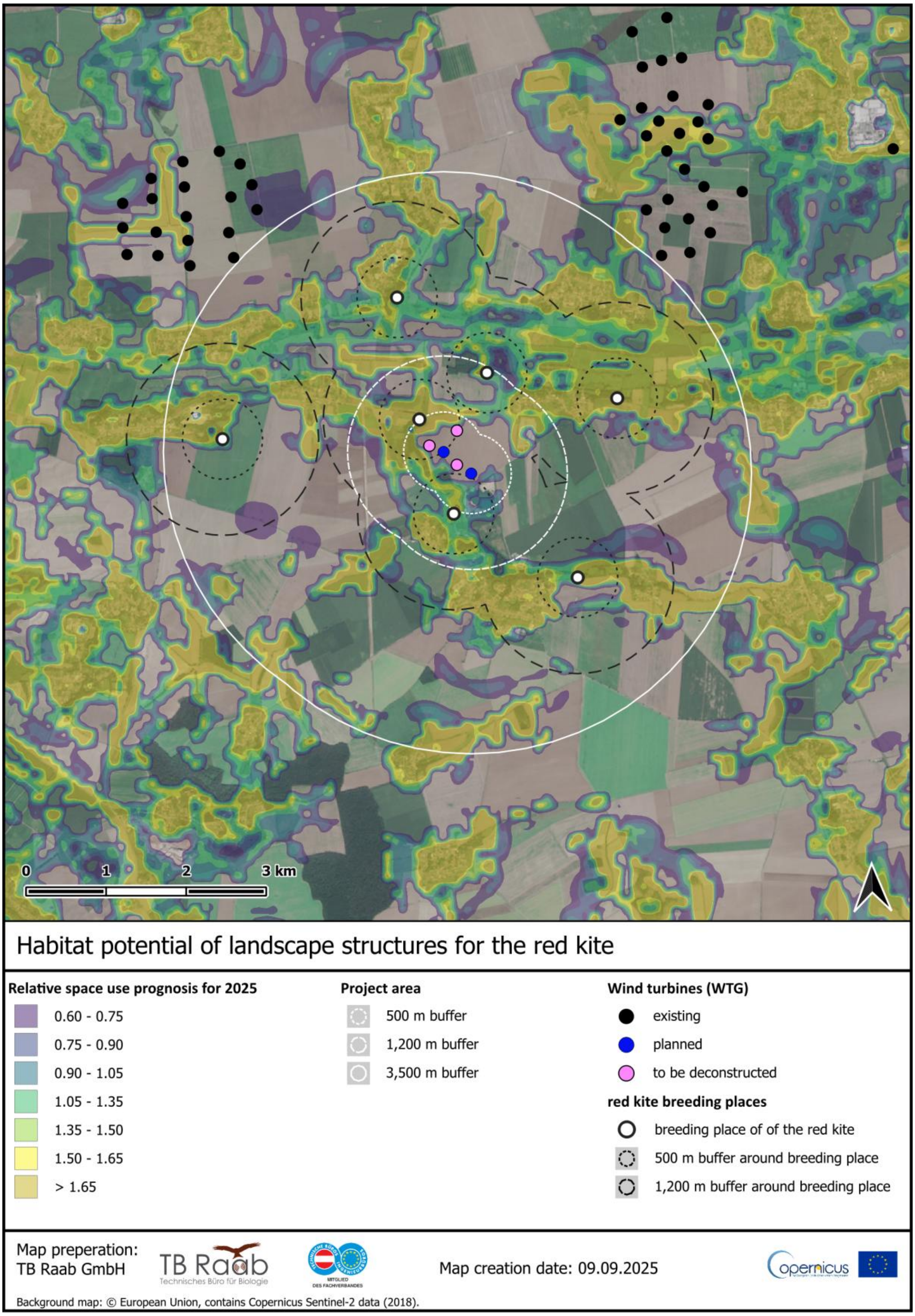

Figure 5: Relative habitat preference as the predicted relative daytime residence time of breeding birds, excluding the parameter distance to breeding place, based on the habitat parameters of the RKR model. Within the 1,200 m central evaluation area there are 3 breeding places of the red kite.

4.1 Breeding place A

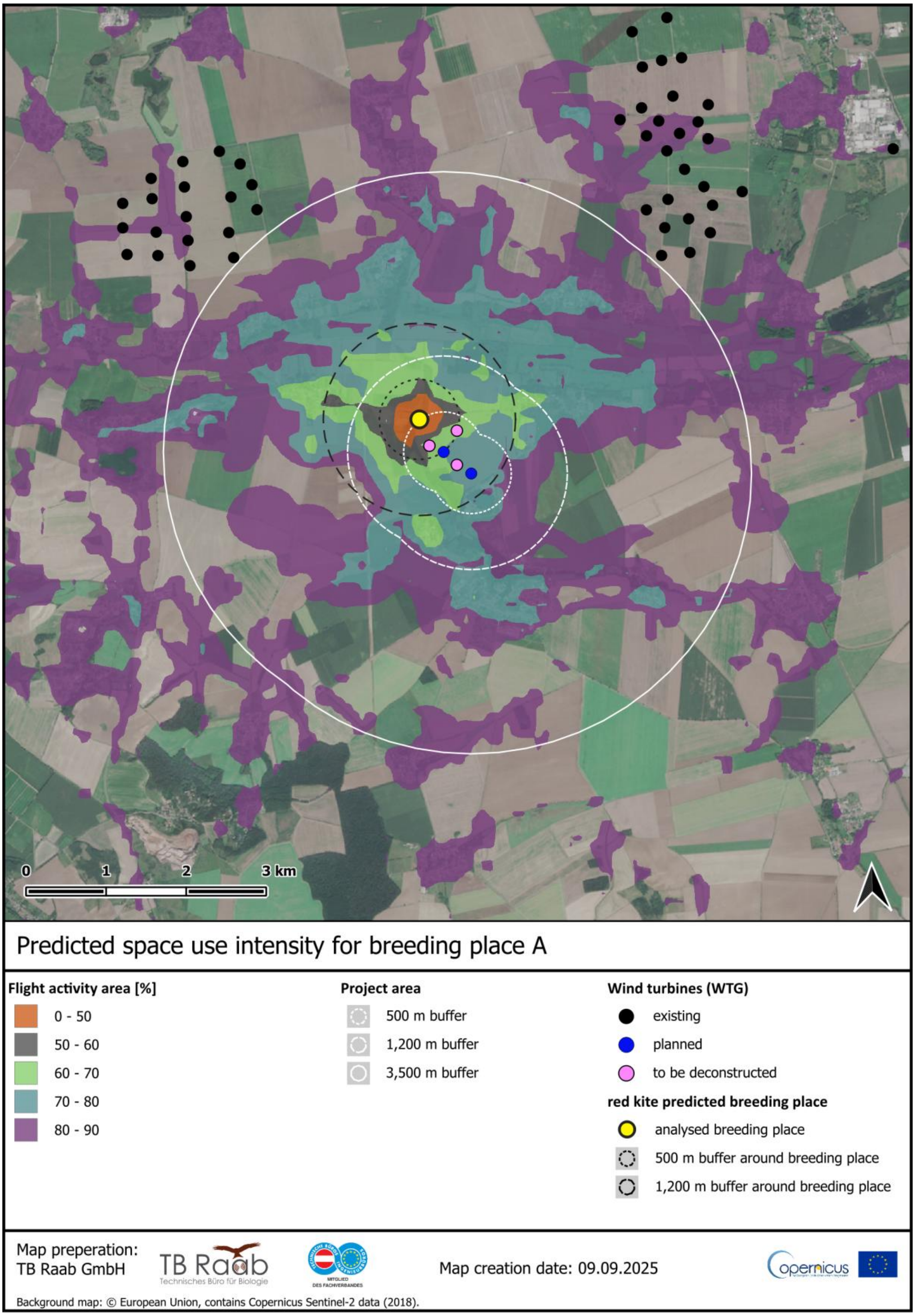

Figure 6: Predicted space use for red kite from the breeding place A during the breeding season, based on 90% of the cumulative flight duration.

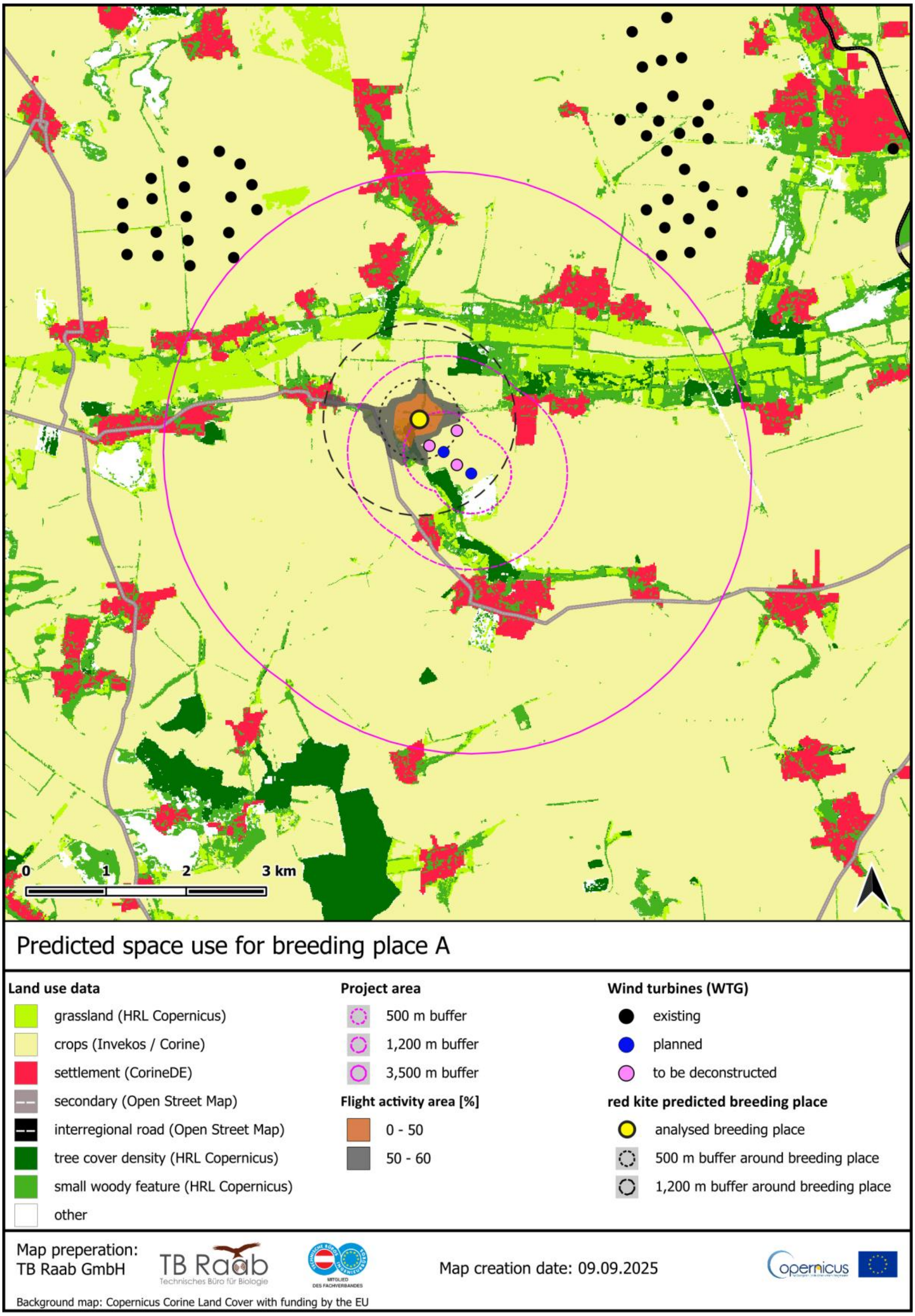

Figure 7: Predicted space use for red kite from the breeding place A during the breeding season, based on 60% of the cumulative flight duration. Representation of the land use categories applied for the RKR prediction.

4.2 Breeding place B

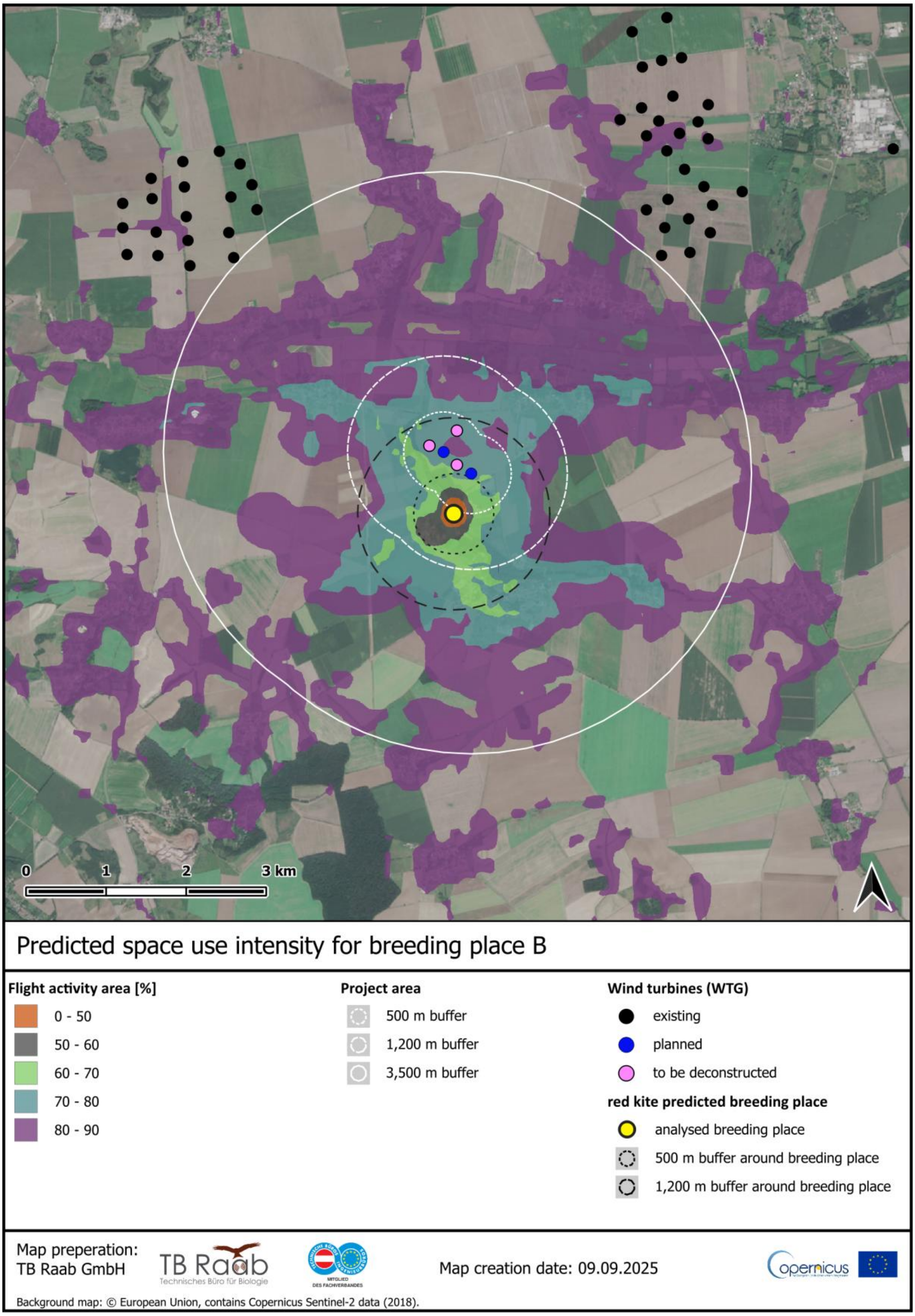

Figure 8: Predicted space use for red kite from the breeding place B during the breeding season, based on 90% of the cumulative flight duration.

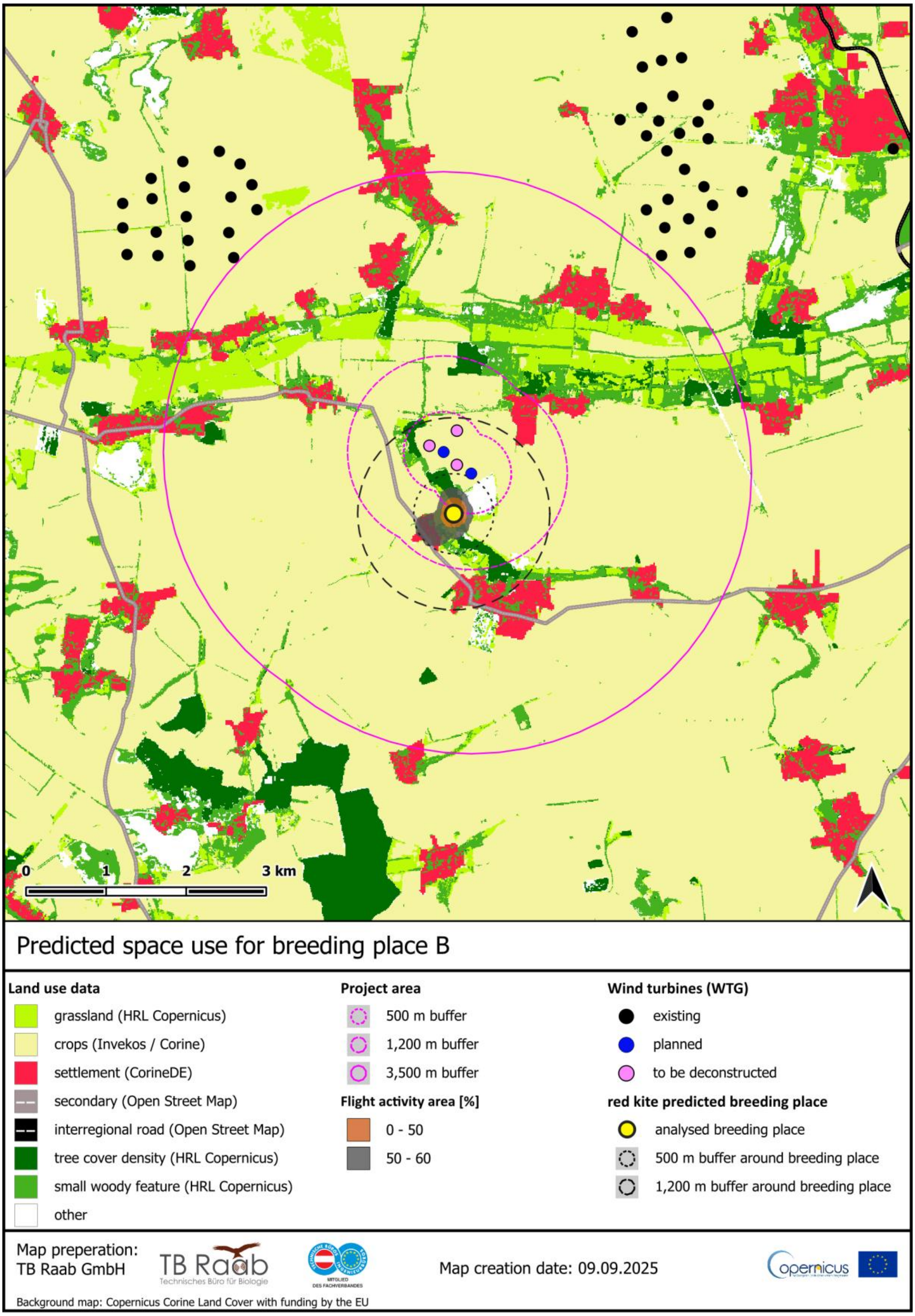

Figure 9: Predicted space use for red kite from the breeding place B during the breeding season, based on 60% of the cumulative flight duration. Representation of the land use categories applied for the RKR prediction.

4.3 Breeding place C

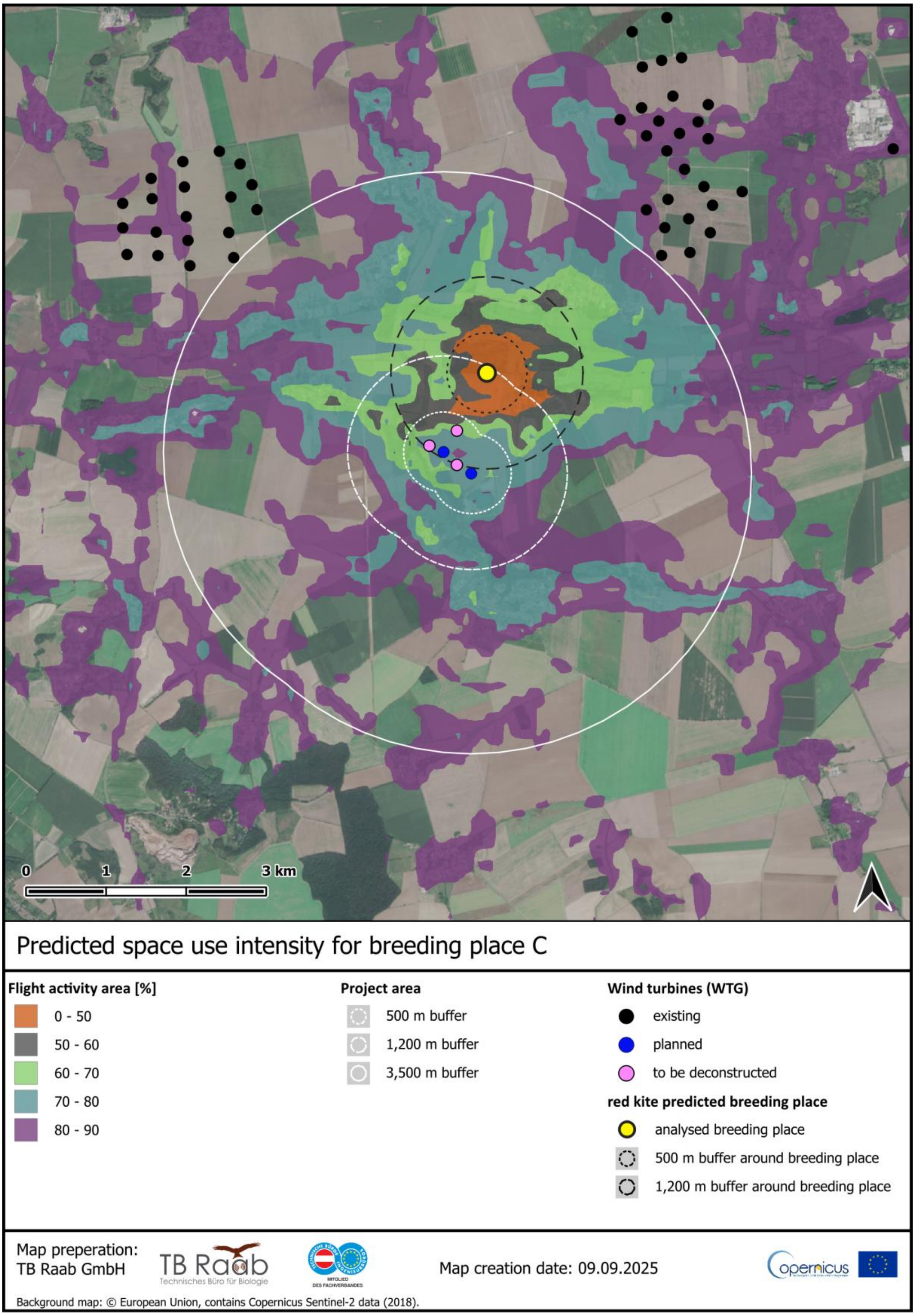

Figure 10: Predicted space use for red kite from the breeding place C during the breeding season, based on 90% of the cumulative flight duration.

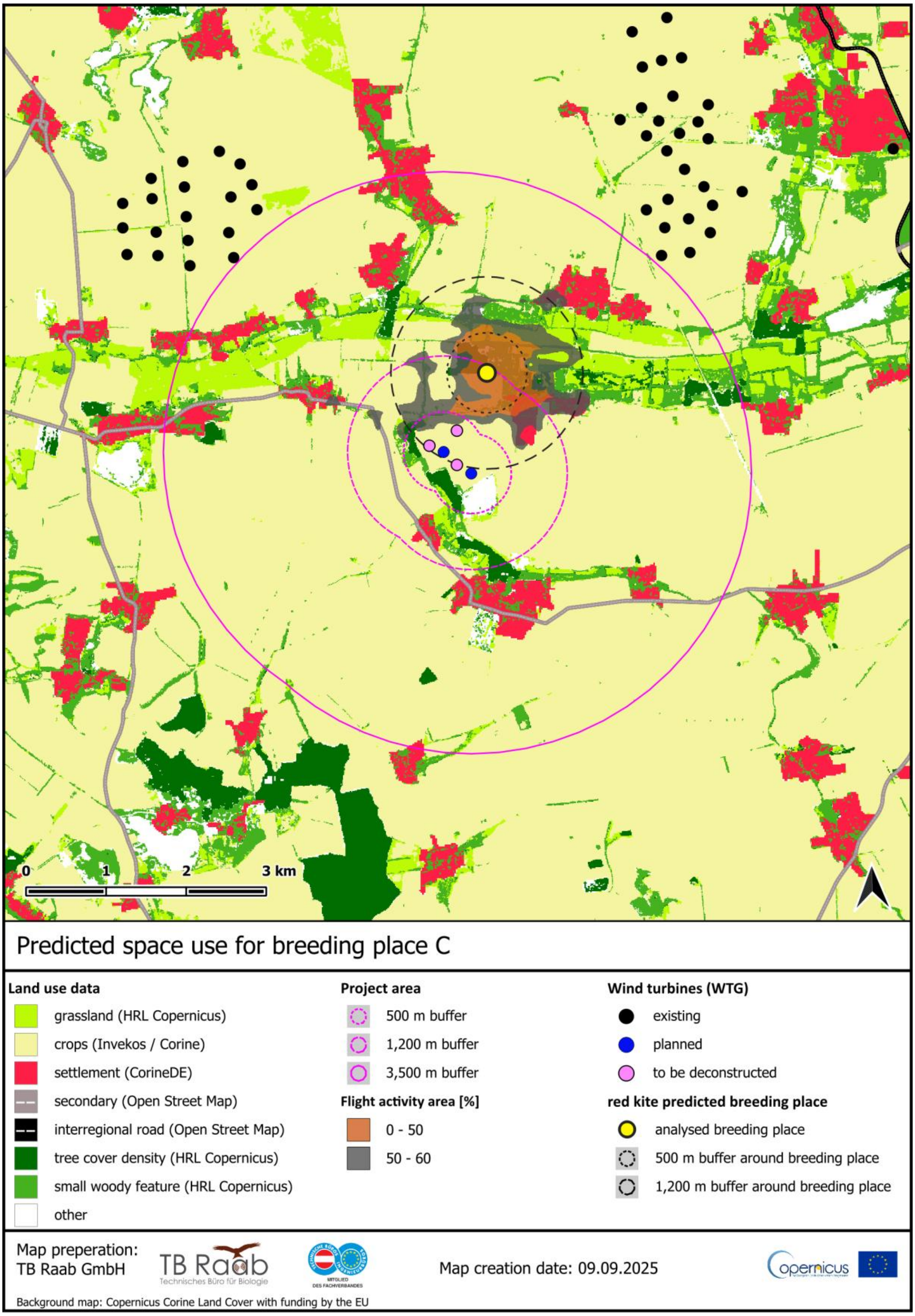

Figure 11: Predicted space use for red kite from the breeding place C during the breeding season, based on 60% of the cumulative flight duration. Representation of the land use categories applied for the RKR prediction.

5. Results & Interpretation

The German Federal Immission Control Act (BImSchG), in its structure, terminology, and administrative practice, is oriented toward the individual WTG as the unit of evaluation. Obligations for protection, permitting requirements, and criteria for examination consistently refer to each individual WTG. The decisive factor for the permitting eligibility of each WTG is the evaluation of whether it poses a significantly increased risk of mortality.

According to Section 45 (3) of the German BNatSchG, there is a rebuttable legal presumption of a significantly increased risk of mortality within the central evaluation area. Pursuant to Section 45 (3) of the German BNatSchG, this presumption can be rebutted either through a habitat potential analysis (HPA) or a space use analysis (RNA).

The application of the RKR model enables a quantified evaluation of habitat potential (see Figure 5) and, building on this, the determination of the space use by the breeding birds relevant to the evaluation. Key factors determining the habitat potential for red kite were empirically identified in the context of the “Fortsetzungsstudie Probabilistik” (Mercker et al., 2024). In particular, grassland, arable land, settlement edges, regional and supra-regional roads, forest areas, and hedgerow structures exert a strong attraction on red kite.

The RKR model, as a probabilistic calculation method, makes it possible to combine technological advances in remote sensing with objective movement data from telemetry. This approach allows standardized, transparent, and precise, scientifically substantiated results to be produced for calculating space use and collision risk of breeding birds at WTGs, accounting for inherent statistical variability and yielding reproducible outcomes. The basis for this is a standardized methodology defined by calculation rules.

Accordingly, in this report, the RKR model is applied as the selected method for habitat potential analysis (see Section 5.2).

5.1 Calculated Collision Risks

The RKR model allows to calculate the specific collision risk of the planned WTGs. It therefore provides a reliable basis for presenting the risk separately for each breeding place. On this basis, the individual risk of killing for breeding birds can be expertly evaluated (cf. Section 44 (1) No. 1 of the German BNatSchG). If necessary, appropriate mitigation measures in accordance with § 45b Annex 1 Section 2 can be selected and technically evaluated based on the results of the RKR model. The methodology of the RKR model is described in the Methods chapter (Chapter 2) and follows the “Fortsetzungsstudie Probabilistik” (Mercker et al., 2024). The collision risks calculated by the RKR model are presented in Table 2.

Within the 1,200 m buffer around the proposed wind turbines, 3 breeding places of the red kite have been identified, which, with their species-specific central evaluation area thus overlap the WTG sites. In Figure 1, these breeding places are highlighted with capital letters, with the designation starting with A and assigned in ascending order of distance from the planned project. All planned wind turbines (WTGs) are located more than 500 m away from existing breeding places of the red kite and are thus situated outside the species-specific close range of the red kite (see § 45b Annex 1 Section 1 of the German Federal Nature Conservation Act). However, the nearest breeding place, with its central evaluation area of 1,200 m, extends into the area of the wind energy planning. For this reason, there is a rebuttable legal presumption that this results in a significantly increased risk of being killed (see Section 45 (3) of the German BNatSchG).

For the breeding birds of red kite the collision risk at the planned WTGs was calculated in accordance with the RKR model. The highest calculated cumulative collision risk for the breeding place A (cf. Figure 12) is mainly due to its distance of 506 m to the next planned WTG. Without taking mitigation measures into account, the expected value of collisions, cumulative for all planned WTGs after project implementation, amounts to 0.007 collisions per individual per year for this breeding place A (see Table 2). Before implementation of the project, the expected number of collisions with the 3 existing WTGs to be repowered for breeding place A amounts to 0.027 collisions per individual per breeding season. In comparison to the existing situation, this results in a reduction of the expected number of collisions for breeding place A by 0.02.

Table 2: Collision risks calculated by the RKR model for known breeding birds of the species red kite in the years 2021, 2022 and 2023 within the surroundings of the project area. The spatial allocation of breeding places and wind turbines can be found in Figure 1. The values represent the estimated risk per breeding bird of colliding with a specific wind turbine within one breeding season. The column Total (planned) shows the cumulative collision risk per breeding bird across all planned turbines within the planned wind farm.

	year	P1	P2	D1	D2	D3	total (decon.)	total (plan.)	total (diff.)
A	2022	**0.00547**	0.00159	0.01562	0.00243	0.00906	0.02691	0.00705	-0.01985
B	2021	0.00199	**0.00446**	0.00215	0.00361	0.00193	0.00767	0.00645	-0.00122
C	2022	0.00149	0.00125	0.00204	0.00130	0.00400	0.00731	0.00274	-0.00457
Delta							-257.89 %	100.0 %	-157.89 %
x1	2022	0.00032	0.00051	0.00035	0.00038	0.00042	0.00116	0.00082	-0.00034
x2	2023	0.00034	0.00024	0.00054	0.00025	0.00065	0.00144	0.00058	-0.00086
x3	2021	0.00025	0.00033	0.00029	0.00026	0.00048	0.00102	0.00057	-0.00045
x4	2022	0.00021	0.00017	0.00033	0.00018	0.00028	0.00079	0.00038	-0.00040

5.2 Impact & Evaluation of the Project

The nearest breeding place, located within the central evaluation area of 1,200 m, overlaps with the designated wind energy planning area. In accordance with German law, this gives rise to a rebuttable legal presumption of a significantly increased risk of mortality (cf. Section 45 (3) of the German BNatSchG). According to Section 45b of the German BNatSchG, this presumption can be rebutted by conducting either a habitat potential analysis (HPA) or a space use analysis (RNA).

Habitat Use Analysis (HPA): With the amendment of the Federal Nature Conservation Act (BNatSchG) – specifically Section 45b of the German BNatSchG – uniform national standards for significance evaluation in wind energy projects were introduced. For 15 breeding bird species at risk of collision, species-specific distances around breeding places (the close range and evaluation areas) now apply.

Within the close range around a red kite breeding place (a radius of 500 m), there is a statutory presumption that a significantly increased risk of mortality exists. If the breeding place is located within the central evaluation area, which for red kite extends up to 1,200 m, this presumption of a significantly increased risk also generally applies. However, this presumption can be rebutted on scientific grounds: Section 45 (3) of the German BNatSchG explicitly provides that the presumption within the evaluation area can be refuted by means of a Habitat Potential Analysis (HPA).

The RKR model for the red kite empirically derives habitat potential based on the effect of factors such as grassland, arable land, settlement areas, regional and supra-regional roads, forest areas, and hedgerow structures, as determined from extensive telemetry data of tagged breeding red kite individuals. The breeding red kite generally benefits from the small-scale, structurally diverse habitats created by hedgerow structures and forest edges, where arable land and grassland areas alternate. Forest areas are not suitable foraging habitats for the red kite and are therefore avoided away from the breeding place. Anthropogenic, i.e., human-made structures, are used by the red kite for foraging. Waste, carrion, as well as roadkill or mowing victims, are considered important food sources, particularly during the breeding season.

Using the RKR model, habitat effects on the space use of breeding red kite can be predicted and visualised independently of the distance to a specific breeding place. This is referred to as the "habitat potential" (see Figure 5). Typically, in the course of a habitat potential analysis, the expected space use for relevant breeding place is qualitatively derived from the habitat potential. The following section describes how such an analysis is carried out using the RKR model, which determines space use based on the breeding place location and the habitat potential.

The RKR model fulfils the purpose of an HPA, namely to forecast the anticipated space use of the birds on the basis of habitat structures. The HPA 2023 technical concept (Reichenbach et al.,2023, commissioned by the BMWK) highlights that the HPA should in future be supplemented by probabilistic models. The legislator therefore explicitly allows and promotes the integration of advanced models such as the RKR model in order to represent space use and collision risk as realistically as possible.

The introduction of Section 45b of the German BNatSchG fundamentally envisages the HPA approach; however, to date, no HPA method has been formally established by regulation or technical convention. The development of the RKR model itself was initiated and accompanied to a significant extent by specialist authorities.

In the UAG 2 "Probabilistics" working group (a sub-working group of the UMK), more than 30 experts from federal and state authorities as well as scientific institutions reviewed and further developed the model (predictbird.de). External validations confirm its reliability: The model's predictions of space use and collision casualties correspond closely with empirical field data.

Space Use Analysis (RNA): A space use analysis (RNA) is a scientific method for recording and analysing the spatial and temporal behaviour of large birds within a defined area—generally in the vicinity of planned WTGs. The aim is to capture the actual use of the landscape by a target species in order to reliably assess the individual or population-level mortality risk resulting from potential collisions with a WTG (Liesenjohann et al., 2023).

According to § 45b BNatSchG, the space use analysis is explicitly mentioned as one of several possible methods:

"If a significantly increased risk of mortality […] is to be assumed, this presumption can be rebutted by means of a habitat potential analysis or a specific space use analysis that is suitable in the individual case to quantify actual spatial use" (§ 45b para. 3 sentence 1 no. 1 BNatSchG).

In the so-called “central evaluation area” for red kite up to 1,200 m from the breeding place, the implementation of a habitat potential analysis (HPA) is the primary method. A space use analysis can be conducted in addition or as an alternative, in particular at the request of the project developer if they wish to demonstrate that the risk is lower than assumed under the legal presumption (KNE, 2023).

In contrast to the qualitatively interpretative HPA, which uses a modelling approach—such as the RKR model—to derive probable use based on habitat structures and species-specific requirements, the RNA empirically records actual space use (Reichenbach et al., 2023). The RNA primarily serves to substantiate exemptions pursuant to Section 45b (7) of the German BNatSchG or to verify the plausibility of the HPA within the evaluation areas. In addition, it can be used to assess the effectiveness of avoidance or shutdown measures. In legally or conservation-related particularly sensitive cases, for example in the immediate vicinity of breeding places of strictly protected species, the RNA is also applied.

The RKR model developed by Mercker et al. (2024) meets the requirements of a quantitative and empirically based assessment of space use in accordance with Section 45b of the German BNatSchG. Scientifically, the model provides a robust, data-based forecast of space use and collision probability for the specific breeding place—precisely those parameters that are decisive for evaluating significant risk.

From a legal and policy perspective, this method is already supported: In 2023, the German Federal Government endorsed the introduction of this probabilistic approach (BMUV, 2023) in order to make the legally prescribed exemption assessment more efficient and objective. The model combines scientific evidence with administrative recognition, enabling project developers to use it within the applicable legal framework to meet species protection requirements as reliably as with a conventional space use analysis.

Favourable foraging habitats for the red kite, such as open land or extensively used agricultural areas, as well as regular flight routes between the breeding places and foraging habitats, are identified using the RKR model. Areas that are particularly intensively used are mapped, and the expected spatial use at the planned wind energy plant locations is determined. According to the guideline for red kite space use analysis by Isselbächer et al. (2018), the area actively used is delineated from areas with low activity by means of a threshold value describing 70% of space use. The guideline for red kite space use analysis by Isselbächer et al. (2018) states: “For areas with below-average activity, it can generally be assumed that there is no significantly increased operational mortality risk. For the area representing 70–80% space use (yellow category), a case-by-case assessment is required (mitigation measures)” (Isselbächer et al., 2018).

According to Isselbächer et al. (2018), a potential need for mitigation measures must be assessed on a case-by-case basis for the WTG P2 (73.5%) (area of 70–80% space use).

It should be noted that the evaluation standard according to Isselbächer et al. (2018) define a very high protective standard. In the discussions surrounding the Progress Study, a threshold of 50 % of flight activity was generally considered as the basis for distance recommendations, whereas for the red kite, as a species for which Germany has special responsibility, a 60 % threshold was recommended.

This recommendation was based on the high proportion of the global population occurring in Germany, which has since decreased significantly, mainly due to population increases in the

UK and other European countries. Based on this 60 % threshold, German federal states in the past established their distance recommendations, which were standardised to 1,200 m with the 2023 amendment of the BNatSchG.

The basic idea behind these distance recommendations is therefore the protection of 60% of flight activity. By applying thresholds of 70–80%, the approach according to Isselbächer goes far beyond this level of protection.

If the evaluation of the need for mitigation measures is carried out in accordance with the original methodology using a 60% threshold, there is no need for measures for the WEA P1 (69.4%) and P2 (73.5%).

While the evaluation based on space use, compared to the evaluation of collision risk, does not take into account parameters of the turbines (e.g., rotor-free space, rotor diameter), these factors are included in the RKR model. Therefore, the final evaluation is subsequently carried out using the expected value for collision risk.

Space Use Collision Risk Model (RKR model): The RKR model, as a probabilistic method, thus enables both the evaluation of habitat potential—analogous to a habitat potential analysis—and the determination of the specific space use of a breeding pair at a known breeding place, analogous to a space use analysis in accordance with Section 45b of the German BNatSchG.

Using the RKR model, a standardised calculation of the expected number of collisions per breeding bird and breeding season can be carried out. This allows the effects of the project to be evaluated on the basis of the predicted collision risk using a professional expert evaluation framework. For this purpose, an extended “traffic light” scheme is applied.

The individual mortality risk for each WEA is classified into the categories green (<1%), blue-grey (1–2%), yellow (2–5%) and red (>5%). “Green” indicates low impact intensity, “blue-grey” moderate, “yellow” high, and “red” very high impact intensity (cf. Table 3 and Figure 12).

Table 3: Categorisation of the calculated collision risks for breeding birds of the species red kite from the years 2021, 2022 and 2023 within the 1,200 m zone of the project area, taking into account the respective impacts of the project. The evaluation is carried out for each WTG (cf. Figure 12).

Wind Turbine	Location	Category	Highest Risk	Impact
P1	Central Evaluation Area	Green	0.00547	low
P2	Central Evaluation Area	Green	0.00446	low

Figure 12: Evaluation of the impacts of each planned WTG in the categories “green,” “blue-grey,” “yellow,” and “red” (see Table 3). For this evaluation, neither mitigation measures nor the removal of existing WTGs, which could contribute to a reduction in collision risk, were taken into account.

5.3 Legal Classification in the context of the Delta Approach

Regarding the repowering project in question 3 breeding places of red kite in the central evaluation area were identified. Accordingly, there is the rebuttable legal presumption that a significantly increased risk of mortality is present (cf. § 45b para. 3 BNatSchG).

It should be noted that, in the case of repowering, the comparison of the effects of the existing project with those of the repowering project (delta analysis) is decisive for determining or rebutting a significantly increased risk of mortality.

In the overall evaluation the comparison of the existing installations with the proposed WTGs shows, based on an increase in rotor radius (from ⌀ 45 m to ⌀ 86 m),, the expansion of the rotor-free area (from ⌀ 60 m to ⌀ 89 m), along with the reduction in the number of WEA from 3 to 2 (see Table 1) and Table 2 that the collision risk for breeding red kite with breeding places in the central evaluation area of the planned installations will be reduced by -157.89% as a result of repowering 3 existing turbines with 2 new turbines, thus resulting in total in a reduced collision risk..

The Delta Analysis within the framework of the RKR model therefore leads to the scientifically substantiated conclusion that the planned project results in a reduction of the collision risk by -157.89 %. The Delta Analysis within the RKR model thus provides scientifically robust evidence that the project will reduce the mortality risk for the red kites breeding in the central evaluation area. A significantly increased mortality risk can therefore be conclusively ruled out.

Beyond the evaluated repowering project, there is therefore no further need for additional measures to reduce the collision risk.

5.4 Final Evaluation

In the overall evaluation, the comparison of the existing installations with the proposed installations results in an increase in rotor radius (from ⌀ 45 m to ⌀ 86 m), the expansion of the rotor-free area (from ⌀ 60 m to ⌀ 89 m) along with the reduction in the number of WEA from 3 to 2 (see Table 1), thus resulting in total in a reduced collision risk..

From the Table 2 it is evident that the collision risk of the red kite breeding birds with breeding places in the central evaluation area of the planned installations, through the repowering of 3 existing installations by 2 new installations, leads to a reduction of the collision risk by -157.89 %. The delta assessment within the framework of the RKR model thus arrives at the scientifically substantiated conclusion that the proposed project leads to a reduction of the mortality risk for the red kite breeding in the central evaluation area, and that a significantly increased mortality risk is therefore unequivocally refuted. There is no need for additional measures to reduce the collision risk beyond the repowering.

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7. Data Licences

Copernicus High Resolution Layer (HRL) des Copernicus Land Monitoring Service mit finanzieller Unterstützung der EU. https://land.copernicus.eu/en/products?tab=explore)

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Open Street Map (OSM – https://www.openstreetmap.de/)

8. Appendix 1: Forest Areas used in the RKR model

The Tree Cover Density 2018 (Copernicus) is a high-resolution geodataset that provides detailed information on tree cover at a 10-meter resolution for Europe. Global Forest Watch provides a processed data set on forest loss for individual years (Interactive World Forest Map & Tree Cover Change Data | GFW) and thus shows areas affected by deforestation and forest degradation. This dataset enables users to monitor changes in forest cover, assess the impact of human activities and develop strategies for conservation and sustainable land management.

If you select the years 2018 to 2023 after downloading the data from Global Forest Watch, you will see the decline in forest for this period. Based on the high-resolution Tree Cover Density 2018 (Copernicus), the cells identified via Global Forest Watch were set to the value zero for the forest percentage. The combination of the Copernicus data on forest cover 2018 with the data from Global Forest Watch enables a high-resolution calculation of the forest cover in 2023 based on satellite data.

According to the calculation rule for the BfN Fortsetzungsstudie Probabilistik (Mercker et al. 2024), the Copernicus forest stock should be used for the model calculation. However, since the Copernicus Land Monitoring Service does not yet have any more recent data than for 2018 and the forest stock has faced major challenges, especially in recent years (in particular reduction of forest areas due to drought and possible subsequent clear-cutting), the forest stock from 2023, determined as described above, is used in the model (see Figure 13). This enables a standardized evaluation of the current condition on a project-specific basis.

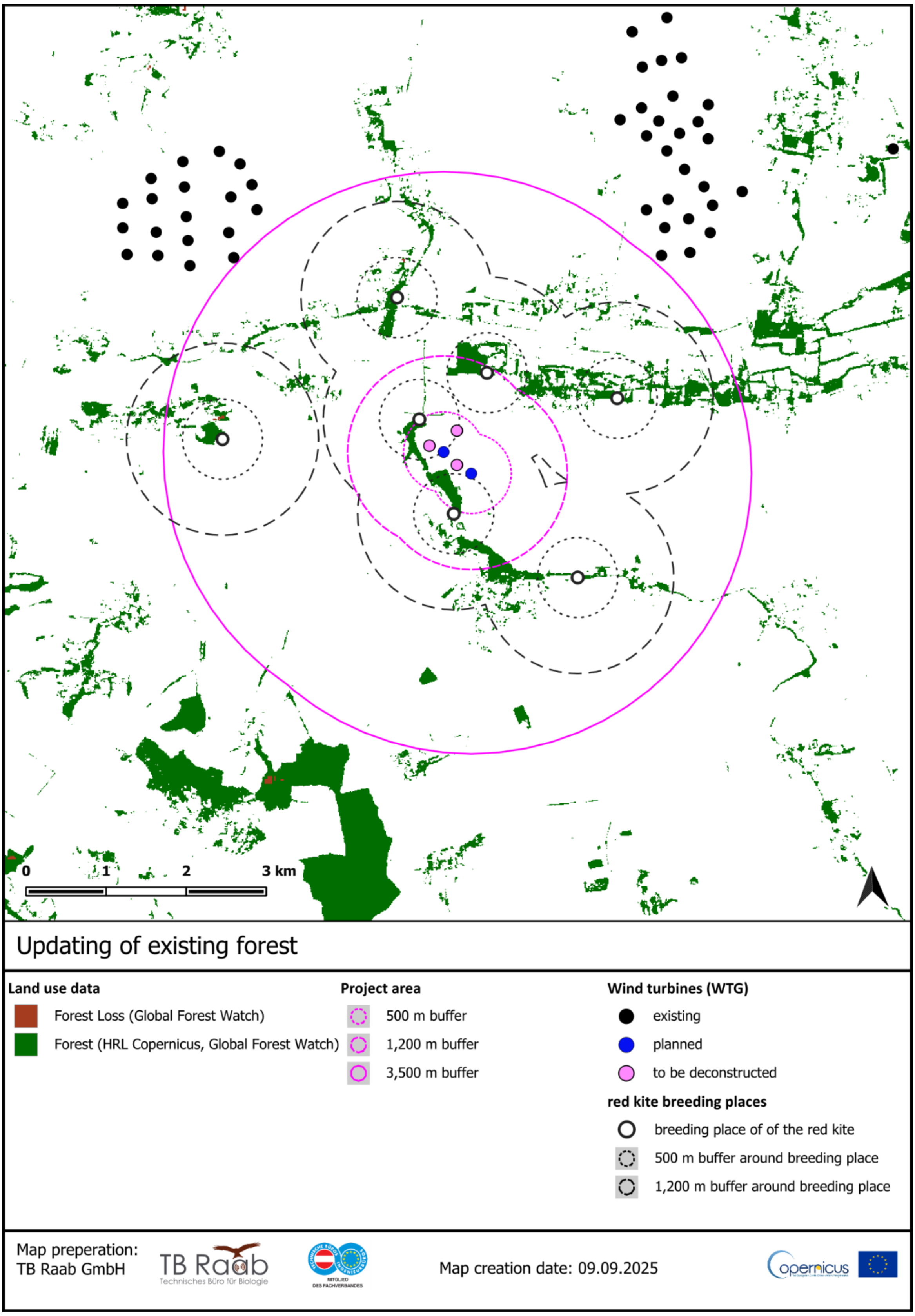

Figure 13: Presentation of the results for the forest areas as of 2023, as determined in the RKR model, based on the “Tree Cover Density” (Copernicus) from 2018 and the “forest loss” data for the years 2018 to 2023 (Global Forest Watch).

9. Appendix 2: Telemetry Data Analysis

The telemetry data from a large number of tagged red kites allow insights into the real space use of young birds, non-breeders and breeding birds for many project areas. This enables the potential identification of local influencing factors that are not described by the model (e.g. the attraction effect of composting facilities). Such factors may need to be taken into account in the expert evaluation.

It should be noted here that the space use of young birds and non-breeders can differ significantly from that of breeding birds, on the one hand due to possibly differing habitat preferences, and on the other hand due to the strong association with local roosting sites instead of a breeding place. In addition, telemetry data outside the breeding season are also taken into account below. Individual and local effects as well as the temporal and spatial fragmentation of the telemetry data also result in a high degree of stochasticity, whereas the RKR model forecasts predict the mean spatial use of breeding birds during the breeding season over an arbitrarily long period (unchanged in terms of habitat). The direct comparison between RKR model predictions and the telemetry data presented is therefore only interpretable to a very limited extent. The Figure 14 shows the telemetry data of young birds, non-breeders and breeding birds from the project area available to the TB Raab. Figure 15 shows the flight time calculated from the telemetry data.

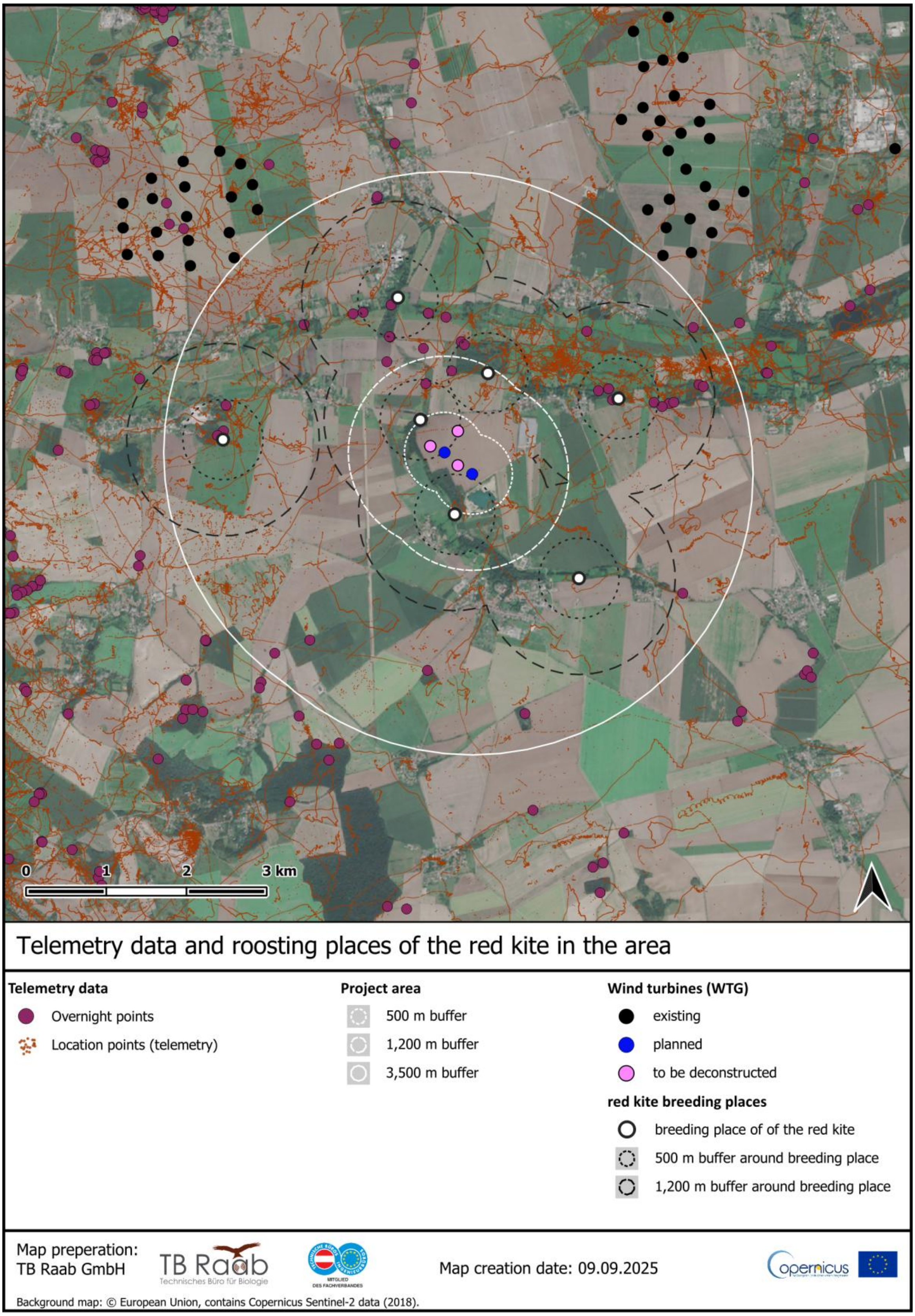

Figure 14: Telemetry data and roosts in the vicinity of the project area. Shown are the known breeding places of the red kite from the years 2021, 2022 and 2023 in the vicinity of the project area.

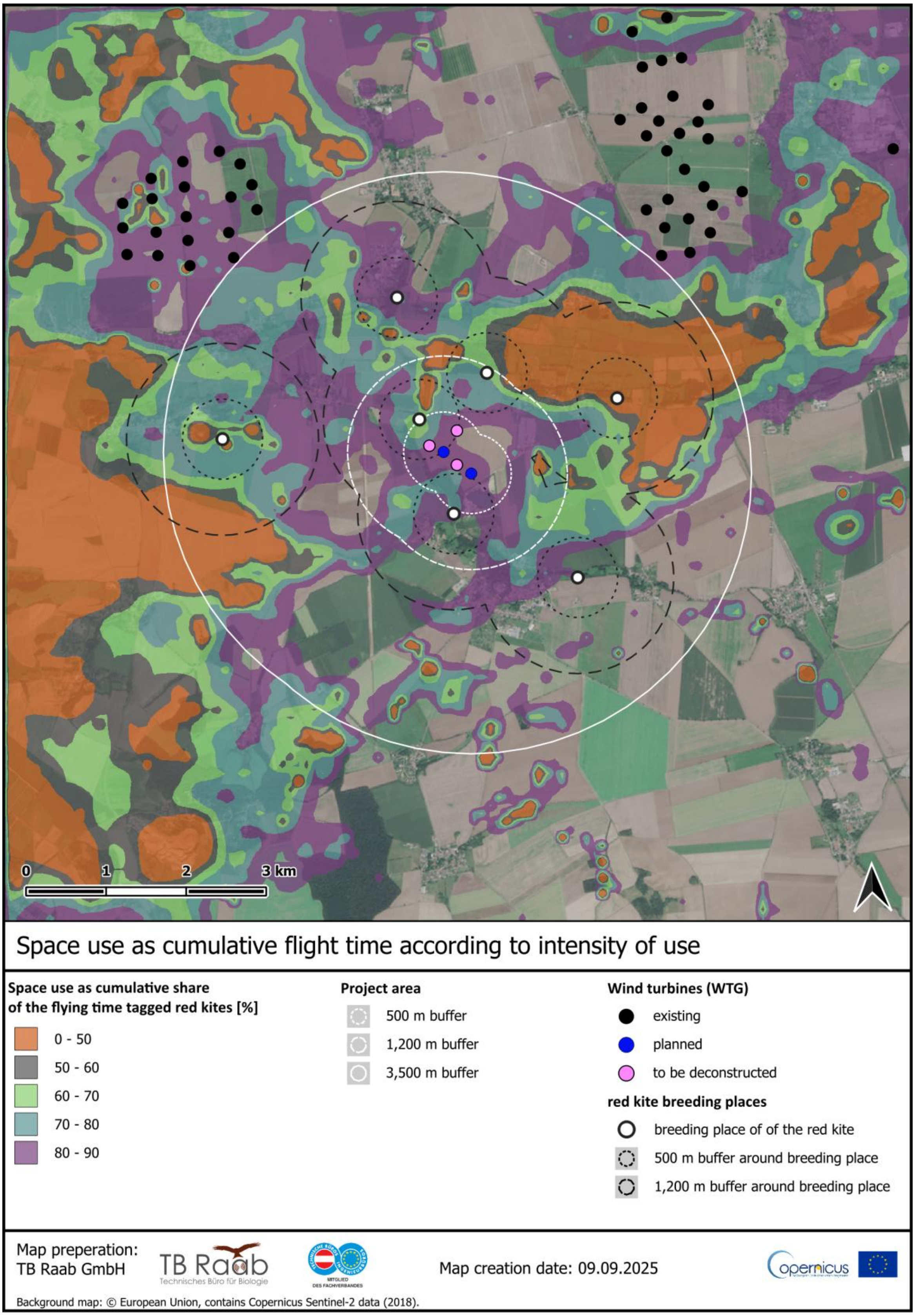

Figure 15: The UD (Utilisation Distribution) derived from all telemetry data describes the smallest possible area in which a certain percentage (50 to 90%) of time spent was recorded. Shown are the known breeding places of the red kite from the years 2021, 2022 and 2023 in the vicinity of the project area.