



EUROPEAN BOWHUNTING FEDERATION

What is the maximal achievable range of a hunting arrow?

European Bowhunting Federation

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Background

- The Flemish agency for Nature and forest (ANB) asked in view of drafting the legalization of bowhunting in Flanders what the maximal range of a hunting arrow can be.
- As no reliable information could be found in literature for arrows equipped with a broadhead, an experiment was needed.

Objective

- Determine the maximum range of a hunting arrow equipped with:
 - Practice field point
 - Broadhead
- Determine the aerodynamic drag coefficient of a hunting arrow

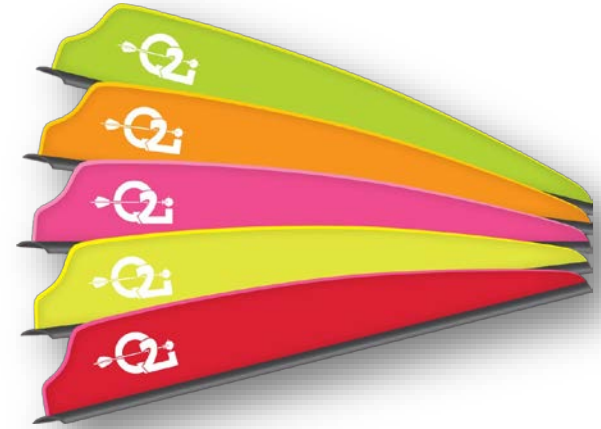
Equipment used (1/3)

- Bow
 - Mathews VX3 29
 - 75 lbs
 - 29.5 draw length
 - IBO rating 350 fps
 - 126.6 J kinetic energy
- Arrow
 - Model: Carbon shaft inner diameter 5 mm, outer diameter 6.82 mm
 - Spine: 250



Equipment used (2/3)

- Vanes
 - Four (4) 2,1" Q2 Archery; Fusion Zeon X-II vanes
 - Helical fletching at $\pm 3^\circ$ angle
 - Length: 2.1" / 53.34 mm
 - Height: 0.44" / 11.176 mm
 - Width: 0.0315" / 0.8001 mm
 - Weight: 5.5 grains / 0.3564 gram
- Field point
 - Saunders Combo 21/64" 125 grain
- Broadhead
 - New Archery Products Thunderhead 125 3- blades, 1 3/16"



Equipment used (3/3)

- Competition Electronics ProChrono Digital Chronograph
- Leica Geovid 2200 laser measuring Binoculars
- Rotary laser receiver; Spectra Precision Laser HL700



Location: Vårby, Sweden

- Possibility to shoot safely 700 m
- Meteorological conditions

Parameter	Value	Unit
Temperature	4	Celcius
Wind	19	km/u
Wind direction	SSW	
Precepitation	0	mm
Air humidity	81	%
Air pressure	982	mb
Altitude Launch	59.055	
Latitude	17.513	
Elevation above sea level launch point	40.00	m
Elevation above sea level arrow landed	40.20	m
Saturation vapor pressure	8.175	hPa
Air density	1.231	kg/m ³

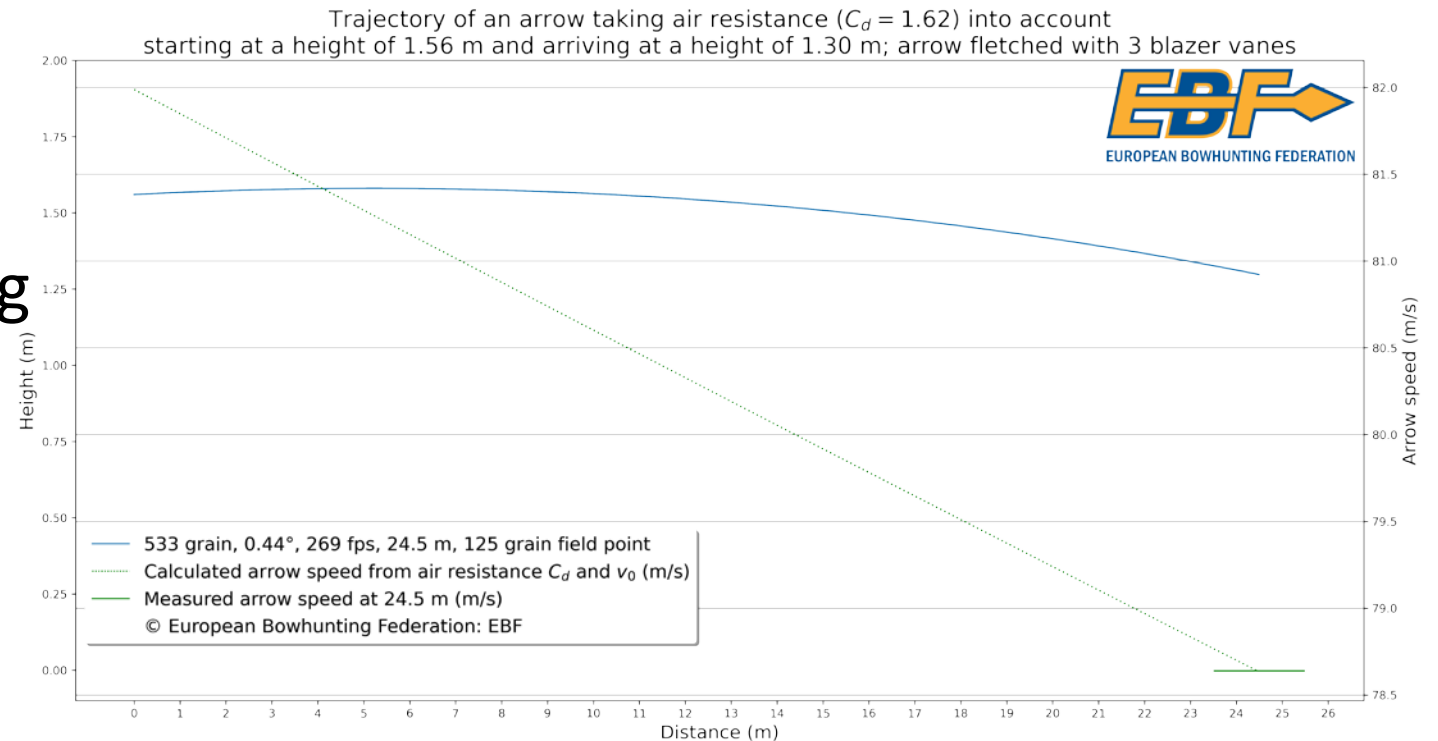


Initial estimation of the drag coefficient

- In order to obtain the most reproducible results, our objective was to launch the arrow at an angle close to the angle where the arrow would go the farthest.
- For this it is necessary to estimate the **drag coefficient (C_d)** because the optimal launching angle depends on this.
- No drag coefficients for arrows with hunting points could be found in literature.

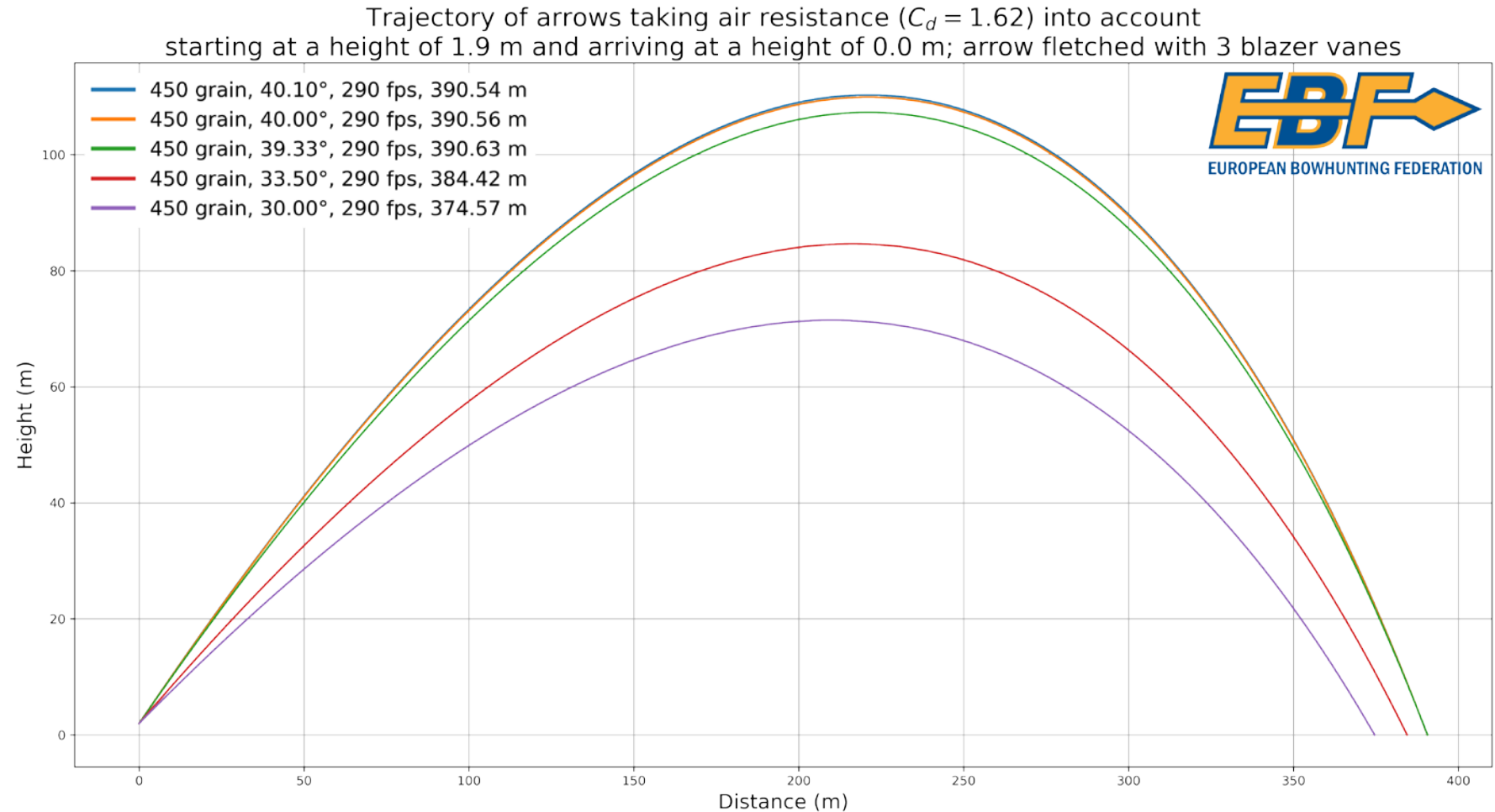
Estimating the drag coefficient of a hunting arrow

- Based on experiments performed in 2015 where the speed of a hunting arrow was measured at 0 and 24.5 meter, we could use the initial estimate for $C_d=1.62$
- Rough estimate
- Can be used to calculate the initial optimal launching angle



Determine the initial optimal launch angle

- Initial $C_d=1.62$
- 450 grain
- ➔ 39.33°



Performed experiment: long distance shot



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Long distance: consistent results



Measurements (1/2)

- Fieldpoints
 - Average distance: $376.6 \pm 3.627\text{m}$; $376.6 \pm 0.96\%$
 - Range: [370 – 382] m
- Broadheads
 - Average distance: $340.1 \pm 5.322\text{ m}$; $340.1 \pm 1.56\%$
 - Range: [332 – 348] m

Parameter	Unit	Global AVG	stdev	RSD	Description	Arrow 1	Arrow 2	Arrow 3	Arrow 4	Arrow 5
Distance	meter	376.6	3.627	0.96%	Fieldpoint series #1	375	375	376	378	379
					Fieldpoint series #2	382	381	377	373	370
Distance	meter	340.1	5.322	1.56%	Broadhead series #1	345	343	337	337	332
					Broadhead series #2	348	339	343	344	333

Measurements (2/2)

Parameter	Unit	Global AVG	stdev	RSD	Description	Arrow 1	Arrow 2	Arrow 3	Arrow 4	Arrow 5
Weight	gram	32.087	0.086	0.27%	Fieldpoint weighing 1	32.20	32.13	31.97	32.02	32.13
					Fieldpoint weighing 2	32.19	32.12	32.01	31.99	32.12
					Fieldpoint weighing 3	32.19	32.11	32.01	31.99	32.12
					Average	32.19	32.12	32.00	32.00	32.12
Parameter	Unit	Global AVG	stdev	RSD	Description	Arrow 1	Arrow 2	Arrow 3	Arrow 4	Arrow 5
Weight	gram	32.166	0.092	0.29%	Broadhead weighing 1	32.27	32.05	32.09	32.20	32.22
					Broadhead weighing 2					
					Broadhead weighing 3					
					Average	32.27	32.05	32.09	32.20	32.22
Parameter	Unit	Global AVG	stdev	RSD	Description	Arrow 1	Arrow 2	Arrow 3	Arrow 4	Arrow 5
Speed	fps	291.067	1.738	0.60%	Fieldpoint speed 1	293	293	292	291	291
					Fieldpoint speed 2	291	294	290	292	288
					Fieldpoint speed 3	291	294	290	288	288
					Average	291.667	293.667	290.667	290.333	289
Speed	fps	291.400	1.817	0.62%	Broadhead speed 1	292	293	290	293	289
					Broadhead speed 2					
					Broadhead speed 3					
					Average	292	293	290	293	289

Calculations

- Used average distances, average weights
- Wind was 19 km/h, SSW
- Arrows were launched 25° from North in the SSE direction
- ➔ wind was at a 47.5° angle from the arrow

Drag force

- $F_d = \frac{1}{2} \rho v^2 C_d A$
 - ρ = *air density (density of the medium)*
 - v = *speed*
 - C_d = *drag coefficient*
 - A = *cross – sectional area*
- Drag force / air resistance is always opposite in direction to the speed of the arrow
- Use an Euler style method (Runge-Kutta*) to calculate the trajectory of the arrow

Drag coefficients

- When taking arrow weight, launch speed, 39° launch angle, 19 km/h wind, etc. into account, what drag coefficient corresponds to an average distance of 376.6m for fieldpoints and 340.1m for broadheads
- Fieldpoints
 - $C_d = 1.4155935$
- Broadheads
 - $C_d = 1.7482892$
 - It is logic that the drag coefficient is larger when a fixed broadhead is present.

Interesting simulations

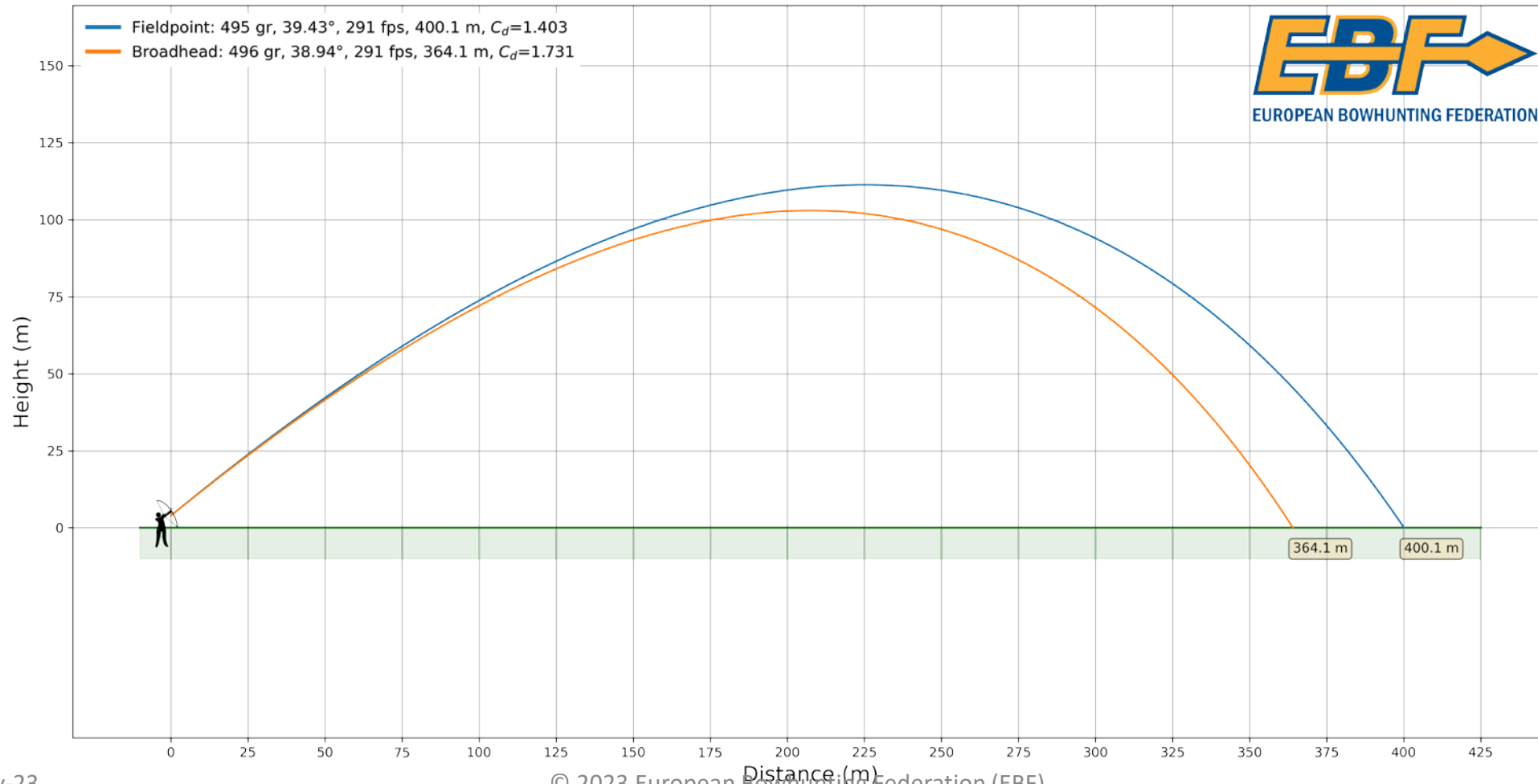
- Now that we have the drag coefficients of the arrows with and without broadhead, we can start doing a set of interesting simulations that can give us relevant information about practical howhunting situations.
 - 1: What is the optimal launch angle that yields the furthest distance?
 - Although every archer knows that this should not be performed, especially not equipped with a broadhead or without flu-flu feathers, still it is an important parameter to use to determine the maximal, worst case, distance of a hunting arrow.
 - 2: How far does an arrow fly when launched perfectly horizontally?
 - Also here, normal shots are always downwards, however, in case of an accidental horizontal shot, how far would the arrow fly?
 - And how far when launched horizontally from a treestand at 6 m height?

1: Calculating the optimal launch angle

- For each of the drag coefficients obtained, the optimal launch angle and maximum distance for our arrow are calculated for a situation without interference from the wind.
- 491 gr, 291 fps, 75# bow, 29.5" draw length, 126.6 J kinetic energy
- Fieldpoints
 - $C_d = 1.4031469$
 - Based on the mean of the distances
 - Optimal angle: 39.39°
 - Maximum distance: **400.1 m**
- Broadheads
 - $C_d = 1.7307692$
 - Based on the mean of the distances
 - Optimal angle: 38.60°
 - Maximum distance: **364.1 m**
- Conclusion: our initial guess of 39° degrees launch angle was very good, supporting the evidence that the experiment was carried out correctly

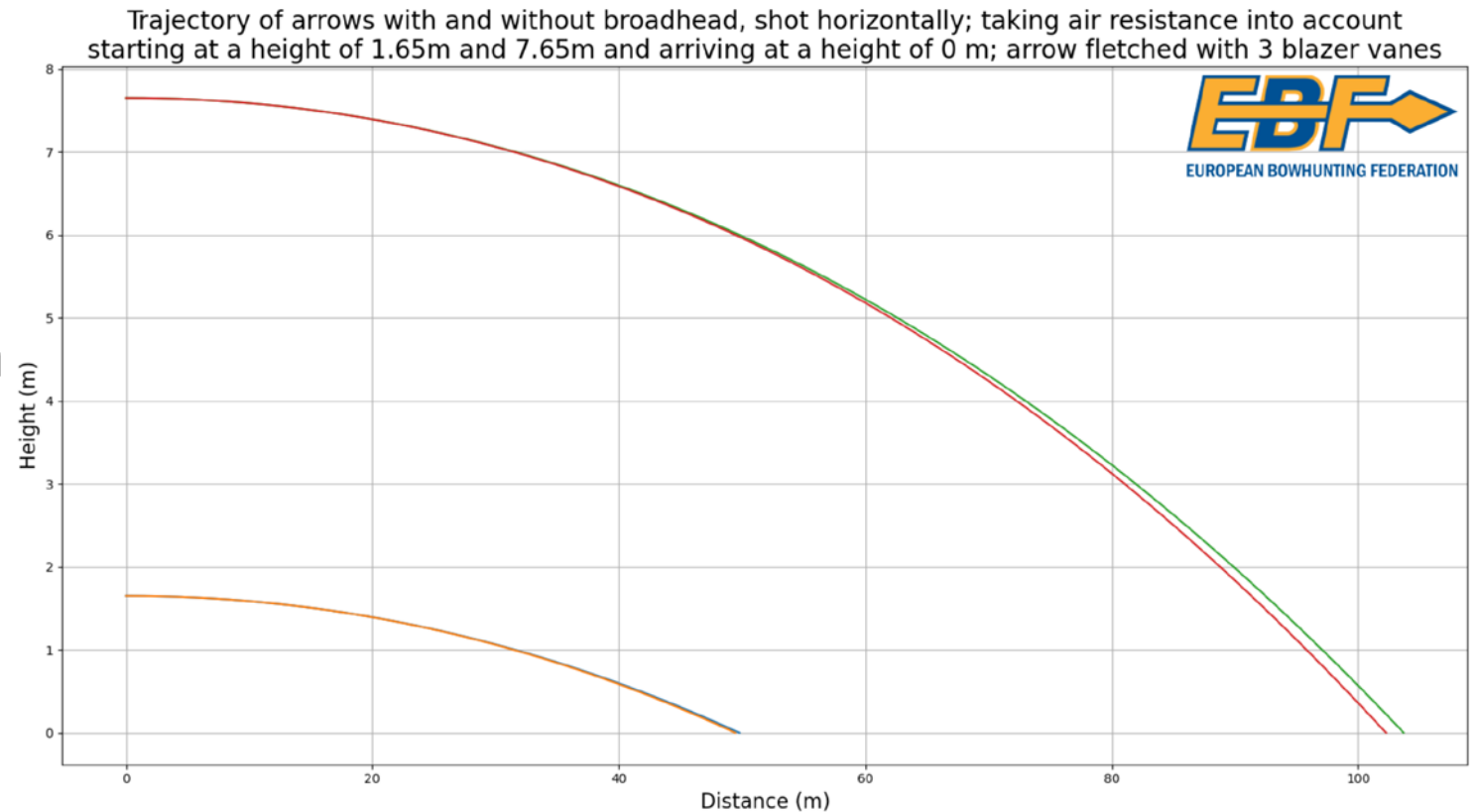
Simulated maximum trajectory

Trajectory of hunting arrows with ($C_d = 1.731$) and without ($C_d = 1.403$) broadhead taking air resistance into account
arrow fletched with 4x Fusion Zeon X-II vanes helical at 3°

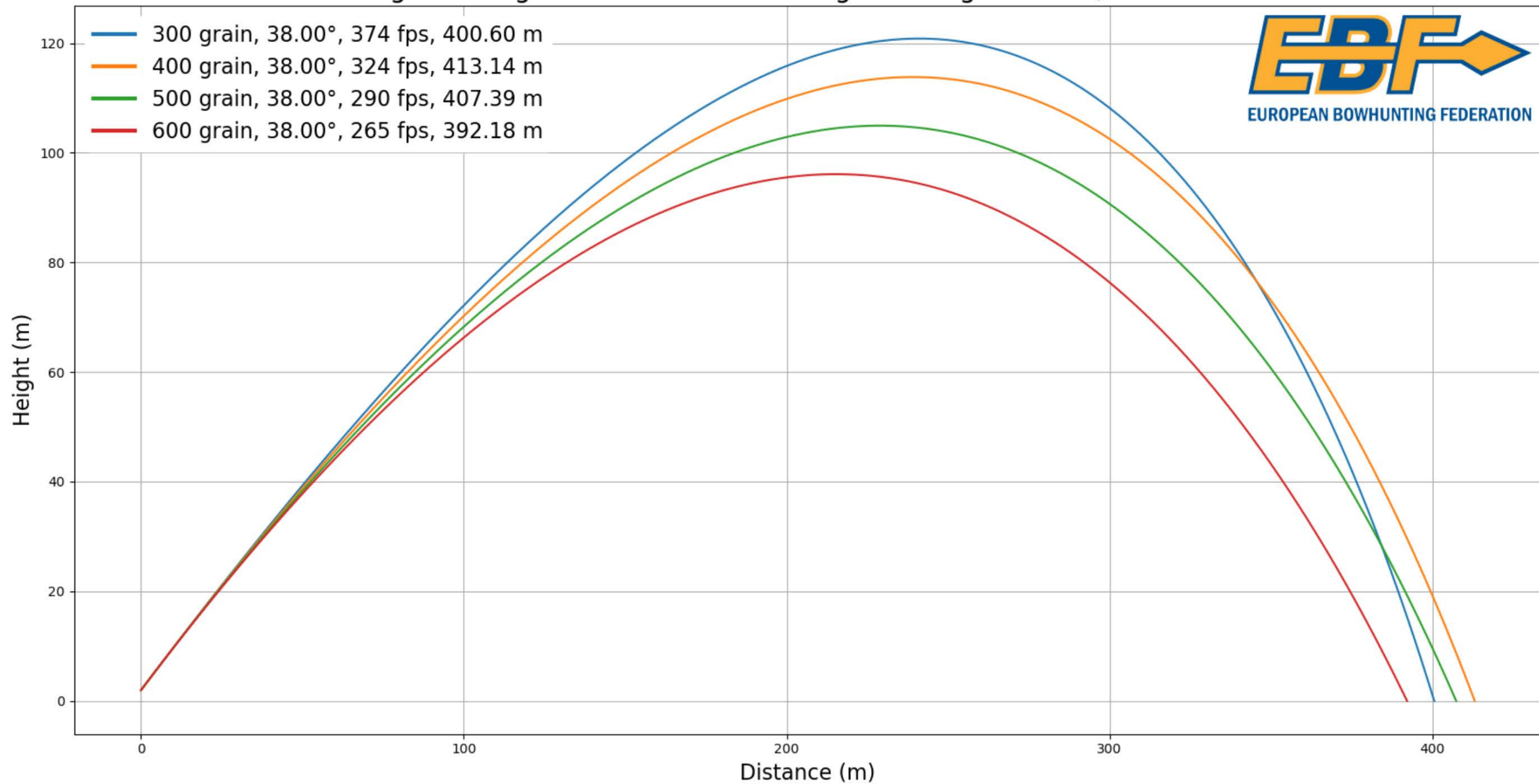


How far does an arrow fly when launched perfectly horizontally?

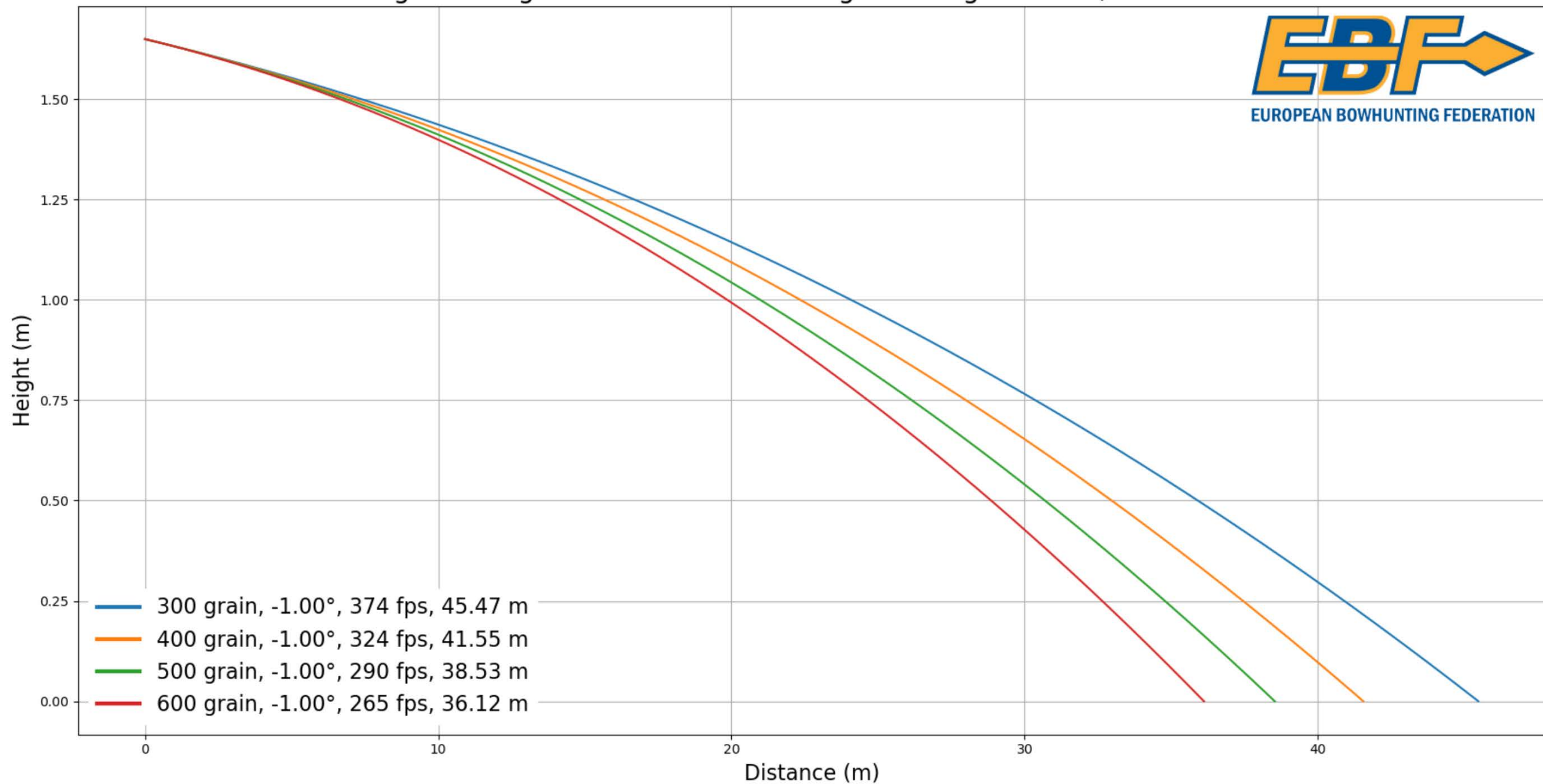
- Ground level
 - Fieldpoint: 50.03 m
 - Broadhead: 49.71m
- Treestand at 6 meter high
 - Fieldpoint: 104.41 m
 - Broadhead: 103.03 m



Trajectory of arrows, constant KE, with broadhead taking air resistance into account
starting at a height of 1.95m and arriving at a height of 0 m; $C_d=1.7307692$



Trajectory of arrows, constant KE, with broadhead taking air resistance into account
starting at a height of 1.65m and arriving at a height of 0 m; $C_d=1.7307692$



Conclusions

- When launched at the optimal trajectory, a typical hunting arrow equipped with a field point and discharged from a 75-pound compound bow is estimated to have a maximum travel distance of approximately 400 meters.
- When equipped with a fixed broadhead, the arrow is expected to experience a reduction in maximum travel distance and would likely travel around 360 meters.



Thanks...